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"TENSE" AND "LAX" STOPS IN KOREAN

Korean is thought to be unique in having three kinds of voiceless stops: aspirated /p^h t^h k^h/, tense /p* t* k*/, and lax /p t k/. The contrast between tense and lax stops raises two theoretical problems. First, to distinguish them either a new feature [tense] is needed, or the contrast in voicing (or aspiration) must be increased from two to three. Either way there is a large increase in the number of possible stops in the world's languages, but the expansion lacks support beyond Korean. Second, initial aspirated and tense consonants correlate with a high tone, and lax and voiced consonants correlate with a low tone. The correlation cannot be explained in the standard tonogenesis model (voiceless-high and voiced-low). We argue instead that (a) underlyingly "tense" stops are regular voiceless unaspirated stops, and "lax" stops are regular voiced stops, (b) there is no compelling evidence for a new distinctive feature, and (c) the consonant-tone correlation is another case of voiceless-high and voiced-low. We conclude that Korean does not have an unusual phonology, and there is no need to complicate feature theory.

1. Introduction

Since C.-W. Kim (1965), it has become widely known that Korean has three kinds of voiceless stops, often described as aspirated /p^h t^h k^h/, tense or fortis /p* t* k*/, and lax or lenis /p t k/. The classic examples are shown in (1).

(1)	/thal/	'mask'
	/t*al/	'daughter'
	/tal/	'moon'

While languages with two kinds of voiceless stops are common, such as Hindi, Thai, and Chinese, Korean is the only language that reportedly has three.

To distinguish three voiceless stops, three proposals have been made. First, one can assume a new feature [tense] (not the same [tense] for vowels; the latter is often called [advanced tongue root]). Second, one can increase voicing contrasts from two to three – voiced, voiceless (the Korean tense stop), and unspecified (the Korean lax stop) – with two features [stiff] and [slack]. Third, one can increase aspiration contrasts from two to three – aspirated, unaspirated (the Korean tense stop), and unspecified (the Korean lax stop) – with two features [spread] and [constricted]. All the proposals have two problems: (a) there is an over-prediction of possible sounds, and (b) a new mechanism in consonant-tone interaction is needed.

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First, consider the over-prediction problem. The traditional features [voice] and [aspirated] give four stops: [p^h p $b^{ɦ}$ b] (ignoring implosives and clicks), all of which have been found. With a new feature [tense], the number is doubled, shown in (2).

(2)	[tense]	–	+	–	+	–	+	–	+
	[aspirated]	–	–	+	+	–	–	+	+
	[voice]	–	–	–	–	+	+	+	+
		p	p*	p^h	p^h*	b	b*	$b^{ɦ}$	$b^{ɦ}$*

However, there is no language that makes use of all the stops, or anywhere close. For example, no language distinguishes [p^h] vs. [p^h*], or [b] vs. [b*], or [$b^{ɦ}$] vs. [$b^{ɦ}$*]. In addition, as Cho et al. (2002) point out, the only language that distinguishes [p] vs. [p*] is Korean. Thus, the Korean case remains unique. Similar problems exist when one expands the voicing or aspiration contrasts from two to three (see below).

Next, consider consonant-tone interaction. Phonetic studies have shown that there is a consonant-tone correlation in the Seoul and Jeonnam (Chonnam) dialects of Korean (hereafter Korean). Specifically, in neutral speech (we will discuss vocative chanting in section 5), if the word initial consonant is voiceless aspirated or voiceless tense, the word has the H pattern (plus a boundary tone), otherwise the word has the LH pattern (plus a boundary tone) (Gim (1969; 1975),[1] Jun (1993), M.-R. Kim (2000), see Figures 1 and 2 in the Appendix). The domain of the consonant-tone correlation has been called an "accentual phrase" (Jun (1993)), which is usually made of a word or a compound plus its suffixes. Thus, in an accentual phrase, tones are predictable from consonant types.

In the standard model of consonant-tone interaction (the tonogenesis model), voiceless consonants correlate with H, and voiced consonants correlate with L (voiceless-H and voiced-L). However, the Korean case presents a problem because voiceless lax stops correlate with LH instead of H. Because of this, Jun (1993; 1996) suggests that Korean tones are not subject to phonetic explanation; instead, they are underlying or a "phonologized" intonational property of a phrase. However, there remains the question of why the consonant-tone correlation is fully predictable from the prevocalic consonant. An alternative proposal is that, in addition to voiceless-H and voiced-L, there are other mechanisms for tonogenesis, such as "tense-H and lax-L", "voiceless-H and unspecified-M", or "non-breathy-H and breathy-L". However, such proposals again lack independent support, and the Korean case remains unique.

There is a third problem with the traditional analysis. Given the tonal difference between words with initial tense stops and those with initial lax stops, there are, in the strict sense, no minimal pairs for voiceless tense and voiceless lax stops. For example, [t*al] and [tal] differ not only in the initial stops but also in the tones of the vowel. This weakens the claim that /t*/ and /t/ are minimally contrastive in Korean.

In this article we offer a different analysis. We propose that the so-called lax stops are underlyingly voiced (similar proposals, such as Kingston and Diehl (1994), will be reviewed below). In accentual-phrase initial position, lax consonants can be devoiced, and their [+voice] feature is spread to the vowel to create L tone. The main advantage of our proposal is that it makes no special assumptions. First, medial lax stops are voiced, in agreement with our underlying representation. Second, initial devoicing is found in other tonogenesis languages. Third, the consonant-tone correlation in Korean is the familiar voiceless-H and voiced-L, and there is no need to assume that Korean tones are unpredictable or assigned by prosodic rules. Fourth, there is no need for a new distinctive feature [tense] nor the need to increase underlying contrasts in voicing (or aspiration) from two to three. In other words, Korean does not have an exotic phonology as previously reported but a regular one.

In section 2 we review the basic facts in Korean, including consonant-tone interactions. In section 3 we offer our analysis. In section 4 we discuss previous analyses. In section 5 we discuss further issues. In section 6 we offer conclusions.

2. Basic Facts

We review three basic facts in Korean: consonant-tone interaction, consonant voicing (also called medial lax voicing), and phonetic differences between tense and lax stops. Following a common approach in generative phonology (Pierrehumbert (1980) and Goldsmith (1981)), we represent both tone and intonation with the same phonological features H (high) and L (low). In addition, we use the term "tone" to refer to all pitch patterns whether they are used to distinguish word meaning (as in Chinese) or not (as in English). This departs from the view that tone and intonation are fundamentally different entities, as expressed in some reviewer comments (to which we will return).

Consonant-tone interaction in Korean has been studied in a number of works (Gim (1969; 1975), Jun (1993), M.-R. Kim (2000)). The effect of consonants on F0 in Korean differs sharply from that in English or French (Jun (1993; 1996), M.-R. Kim (2000)). In the former, the effect can persist through several syllables whereas in the latter the effect only appears at the beginning of a given syllable. For this reason, we follow Jun (1993;

1996) and M.-R. Kim (2000) and consider the effect in Korean to be tonal, in the sense that it should be represented phonologically with tonal features.[2] In contrast, the effect in English and French is phonetic, in the sense that it is local and need not be represented with tonal features.[3] Figures 1 and 2 in the Appendix show the F0 patterns of monosyllables and disyllables in Korean, from M.-R. Kim (2000). The pitch contours suggest two basic tonal patterns, H and LH, illustrated with stops and nasals in (3) for monosyllables and (4) for disyllables. Other consonants, especially fricatives and the so-called "ieung" initial, will be discussed in section 5. Following the tradition, tense consonants are indicated with an asterisk (such as [t*]) and lax stops are written as plain voiceless stops. Tones on different syllable are separated by a hyphen.

(3)	Word	Gloss	Tonal pattern	Tones on syllables
	[tʰal]	'mask'	H	H
	[t*al]	'daughter'	H	H
	[tal]	'moon'	LH	LH
	[mal]	'horse'	LH	LH

(4)	Word	Gloss	Tonal pattern	Tones on syllables
	[pʰaraŋ]	'blue'	H	H-H
	[p*algaŋ]	'red'	H	H-H
	[param]	'wind'	LH	L-H
	[mallaŋ]	'soft'	LH	L-H

Each basic tonal pattern can be followed by a boundary tone, which may differ in different dialects (Jun (1993) and Gim (1997)), or even within the same dialect (M.-R. Kim (2000)). For example, the H pattern could be H+H% or H+L%, and the L pattern could be LH+H% or LH+L%, where H% and L% are boundary tones. Since the variation of the boundary tone does not affect our discussion, they are ignored here. The examples show that the tonal pattern of a word is determined solely by the initial consonant. In contrast, medial consonants do not affect tone, as shown in (5).

(5)	Word	Gloss	Tonal pattern	Tones on syllables
	[pʰadaŋ]	'group'	H	H-H
	[pʰatʰan]	'catastrophe'	H	H-H
	[pʰaraŋ]	'blue'	H	H-H
	[madaŋ]	'yard'	LH	L-H
	[mat*aŋ]	'of course'	LH	L-H
	[mallaŋ]	'soft'	LH	L-H

In (5), the tonal pattern of the first three words is determined by the initial consonant. Whether the medial consonant is lax, voiceless aspirated, or voiced sonorant has no effect. Similarly, the tonal pattern of the last three words is determined by the initial consonant, and the medial consonants have no effect.

Longer words also show the same two tonal patterns although the tone may vary from the third syllable on. Two words are shown in (6).

(6)	Word	Gloss	Tonal pattern	Tones on syllables
	[harabədʒi]	'grandfather'	H	H-H-H-H
				H-H-L-L
	[turumagi]	'Korean topcoat'	LH	L-H-H-H
				L-H-L-L

The variation suggests an optional rightward spreading of the H tone. Jun (1993, p. 42; 1996, p. 97; 1998, p. 193) suggests that in long words the H pattern is HHL in Jeonnam Korean but HHLH in Seoul Korean, and the LH pattern is LHL in Jeonnam Korean but LHLH in Seoul Korean. In the model of Pierrehumbert (1980), the final H in Seoul Korean can be attributed to a boundary tone. On the other hand, M.-R. Kim (2000) did not find a consistent difference between the two dialects, and Seoul Korean does not always end in H. In the discussion below we will focus on the correlation between the initial consonant and the H and LH patterns and ignore the variation in the realization of the two patterns or the effect of boundary tones.

Next consider the voicing of medial stops. In traditional descriptions (Martin (1954), C.-W. Kim (1965), Kim-Renaud (1974), Ahn (1985), Huh (1985), K.-H. Kim (1987)), aspirated and tense stops are voiceless throughout, but lax stop are voiceless initially and voiced medially. This is illustrated in (7) for the labial place. The condition "initial" is often taken to be word initial, but a more accurate description is accentual-phrase initial (Jun (1993)).

(7)		Initial	Medial
	Aspirated	[p^h]	[p^h]
	Tense	[p*]	[p*]
	Lax	[p]	[b]

Some recent studies have found that lax stops are not always voiceless initially and not always fully voiced medially. For example, Silva (1992) reports that voicing of lax stops occurs not only word-medially but also word-initially. Similarly, Jun (1994) reports that word medial lax stops can remain voiceless when the preceding high vowel is devoiced. However, they both agree that when a medial lax stop is truly between two voiced sounds, it is overwhelmingly voiced or partly voiced. Thus, we will follow traditional descriptions and assume that medial lax consonants are voiced. We will return to variation in voicing in section 5.

Next consider phonetic differences between tense and lax stops, which have been discussed in many studies (Lisker and Abramson (1964), C.-W. Kim (1965; 1970), Han and Weitzman (1970), Abramson and Lisker (1972), Hardcastle (1973), Hirose et al. (1974), Kagaya (1974), Dart (1987), Silva (1992), M.-R. Cho Kim (1994), Cho (1996), Han (1996), Shimizu (1996), Jun et al. (1998), Ahn (1999), M.-R. Kim (2000), Cho et al. (2002), M.-R. Kim et al. (2002)). Since tense and lax stops differ in voice medially, most studies focus on the initial position, where both stops are voiceless. We summarize the differences in (8).

(8) Phonetic differences between initial tense and lax stops

	Tense	Lax
Following tone	higher	lower
VOT	shorter	longer
Glottal opening	narrower	wider
H1-H2 (breathiness)	smaller	larger
Intensity	strong	weak
Voicing duration	shorter	longer
Airflow at release	smaller	greater
Air pressure before release	greater	smaller

As discussed earlier, the vowel has H after an initial tense stop and L after an initial lax one. The average VOT difference is quite consistent although there can be overlap (C.-W. Kim (1965), Han and Weitzman (1970), Abramson and Lisker (1972), M.-R. Cho Kim (1994), Shimizu (1996)). In addition, perception studies show that VOT alone is not always sufficient to distinguish tense stops from lax stops. Despite certain overlaps, the overall differences are clear and should be accounted for.

3. Our Analysis

On the suggestion of a reviewer, we offer our analysis first. Our analysis consists of three parts: (a) the analysis of the voicing of the lax stop, (b) the analysis of the consonant-tone interaction, and (c) an explanation of the phonetic differences between tense and lax stops.

3.1. *Voicing of Lax Stops*

Korean has stops (including affricates), fricatives, and sonorants. In this section we focus on stops (we return to other consonants in section 5). According to C.-W. Kim (1965), Korean has three series of stops in syllable onset position, shown in (9). In syllable coda position there is only one series of stops (unreleased and completely neutralized, see Kim and Jongman (1996), H.-S. Kim (1998)), to which we return later.

(9)		Initial onset	Medial onset
	Aspirated	pʰ, tʰ, tʃʰ, kʰ	(same)
	Tense	p*, t*, tʃ*, k*	(same)
	Lax	p, t, tʃ, k	b, d, dʒ, g

As discussed in section 2, aspirated and tense stops are voiceless both initially and medially. Lax stops are voiceless initially and voiced medially when they occur between two voiced sounds.

Since aspirated stops can be distinguished from other stops by the feature [aspirated], the challenge is to distinguish tense and lax stops, which in turn lies in the analysis of lax stops. Since the lax stop has two forms (voiceless and voiced), there are two possible analyses (see section 4 for more proposals). One is to choose the voiceless form as underlying (and propose a voicing rule for the medial environment). If so, we need some feature to distinguish it from the tense stop. The other is to choose the voiced form as underlying (and propose a devoicing rule for the initial environment). If so, the underlying distinction between tense and lax stops lies in voice: the tense stop is [–voice], and the lax stop is [+voice].

Both positions have been pursued. Many studies chose to represent lax stops as underlyingly voiceless, such as C.-W. Kim (1965), Kim-Renaud (1974), Halle and Stevens (1971), Ahn (1985), Huh (1985), K.-H. Kim (1987), Silva (1992), Jun (1993), and Iverson and Salmons (1995). On the other hand, some studies chose to represent lax stops as underlyingly voiced, such as Jones (1950), Hashimoto and Yu (1972), B.-G. Lee (1985), Moon (1974), Oh (1981), Kingston and Diehl (1994), and Choi (1995).

As discussed in section 1, there are three problems with the first approach. First, if tense and lax stops are both voiceless, we need to set up a contrast between them, such as [tense], which then significantly increases the number of possible stops in the world's languages (see (2) and section 4). However, most of the new stops remain hypothetical. Second, if lax stops are voiceless, then the consonant-tone correlation in Korean cannot be explained in standard tonogenesis theory. Instead, a special mechanism is needed. Third, given the fact that initial tense and lax stops trigger a tonal difference, there is no genuine minimal pair for voiceless tense and voiceless lax stops.

The second approach can account for the consonant-tone correlation in standard tonogenesis theory, as suggested by Kingston and Diehl (1994). The question now is, is there still a three-way contrast in initial stops? If there is, we still need to find a featural difference (other than voice) between initial tense and lax stops, and as a result we lose the motivation for the second approach: it assumes just as many features and faces the same problem of over-prediction as the first approach.

Kingston and Diehl (1994) propose a variant of the second approach. They suggest that the initial lax stop remains voiced in the surface phonological representation even though it is phonetically voiceless. Their analysis is shown in (10).

(10)	"Aspirated"	[t^hal]	'mask'
	"Tense"	[tal]	'daughter'
	"Lax"	[dal]	'moon'

In this analysis, one must assume that a phonological feature [+voice] can be realized in different ways phonetically.

Our analysis follows the second approach in representing the lax stop as a plain voiced stop underlyingly. In addition, we argue that it is possible to distinguish syllables with tense and lax stops without a new feature. The solution lies in tone, whose role has so far been ignored. As discussed in section 2, words with initial aspirated and tense stops have H, and words with initial lax stops have L (or LH). The words in (10) are analyzed in (11), where the tone of [á] is H and that of [ǎ] is LH.

(11)	[t^hál]	'mask'
	[tál]	'daughter'
	[d̥ǎl]([tǎl])	'moon'

In this analysis, the first two words differ in initial stops only (aspirated vs. unaspirated), as previously thought. However, the second two words differ in tonal features, namely, H vs. LH, as proposed by Jun (1993) and M.-R. Kim (2000). The question now is: where does the contrast lie in the second two words – in the initial stops themselves or in the tones?

A reviewer argues that, since tone is not lexically specified in Korean, it cannot serve a contrastive function even if it is present at the surface level. Therefore, the contrast lies in the initial stops. There are several problems with the argument. First, any phonological feature can potentially serve a contrastive function if it is present at the surface level even if it is not specified underlyingly. A phonological feature is one that is robust enough articulatorily and perceptually and is known to serve a contrastive function in some language. Consider a case in American English, where /k/ and /g/ can contrast in either [voice] or [aspirated]. This is illustrated in (12).

(12)	a. Contrast in [voice]		b. Contrast in [aspirated]	
	[bækr]	'backer'	$[k^het]$	'Kate'
	[bægr]	'bagger'	[ket]	'gate'

In (12a), the basic contrast (or the basic articulatory gesture) between /k/ and /g/ is in [voice] (medial /k/ is unaspirated in American English). In (12b), the basic contrast between /k/ and /g/ is in [aspirated] (English /g/ often becomes devoiced [k] initially). In the standard analysis, /k/ and /g/ differ in [voice] underlyingly. However, in (12b) the contrast is shifted to [aspirated], which is not specified underlyingly.[4] Likewise, since tone is a phonological feature (known to serve a contrastive function in many Asian and African languages), and since it is present at the surface level in Korean, it can serve a contrastive function. If so, there is no longer a need to assume a new phonological feature for the initial stops.

Second, the reviewer assumes that voicing and tone are totally different features. However, according to Halle and Stevens (1971), voicing and tone involve the same phonological feature (see below).

Third, the reviewer seems to assume that an underlying feature must stay on the original sound and cannot move to another sound, but this cannot be the case. For example, an underlying VN rime in French is realized as a nasalized vowel Ṽ, where the feature [nasal] has moved from the coda to the vowel. A similar case is found in Standard Chinese, which is shown in (13).

(13) /kan/ → [kæ̃] 'dry'
/kaŋ/ → [kɑ̃] 'steel'

Standard Chinese has only one low vowel, unspecified for [back], represented as /a/ here. In addition, Standard Chinese has two underlying nasal codas, /n/ and /ŋ/. At the surface level, the nasal codas can change the backness of /a/, nasalized it, and lose their own oral closure (Xu (1986), Wang (1993, chapter 6; 1997), Duanmu (2002)). In other words, not only did the feature [nasal] move from the coda to the vowel, but the underlying contrast between /n/ and /ŋ/ has changed to a surface difference in [back] in the vowel even though [back] is underlyingly unspecified for /a/. This again shows that an underlying feature can be realized not only on a different sound but also as a different surface feature.

Now if the tonal difference can bear the contrast between words like [tál] and [d̥ăl]([tăl]), there is no need to assume a new feature for the initial stops.

For orthographic distinction, we show the initial lax stop as a devoiced stop, which need not have different features from a regular voiceless stop (see below). In (14) we compare the three approaches.

(14)		Previous1		Previous2		Present	
		Tense	Lax	Tense	Lax	Tense	Lax
	Initial	p*	p	p	b	p	b̥ (p)
	Contrast in	[tense]		[voice]		tone	
	Medial	p*	b	p	b	p	b
	Contrast in	[tense]/[voice]		[voice]		[voice]	

In the first approach, tense and lax stops contrast in [tense] initially; medially, they also contrast in [tense] and probably in [voice] as well. In the second approach, tense and lax stops contrast in [voice] initially and medially. In the present approach, tense and lax stops contrast in [voice] medially; in initial position, the contrast is shifted to tone on the vowel. The remaining phonetic differences between initial tense and lax stops will be discussed in section 3.3.

3.2. *Analysis of Consonant-tone Correlation*

We first review two theories of tonogenesis, a listener-based theory (Hombert et al. (1979)) and a feature-spreading theory (Halle and Stevens (1971)). Then we discuss the analysis of Korean.

3.2.1. *Theories of tonogenesis*

Tonogenesis refers to the development of tone from the influence of neighboring consonants (Matisoff (1973) and references therein). Both onset and coda consonants of a syllable can influence its tone (e.g., Haudricourt (1954) for Vietnamese and Baxter (1992) for Chinese). In this article we focus on the influence of onset consonants, which has been called voiceless-high and voiced-low, that is, a voiceless onset consonant triggers a high tone, and a voiced onset consonant triggers a low tone. An example from Lhasa Tibetan is shown in (15), where H is a high tone and LH is a rising tone on a monosyllable (Hu (1980, p. 31), Duanmu (1992b)).

(15)

Historical Tibetan	Lhasa Tibetan		
ko	ko	H	'he'
go	ko	LH	'hear'
to	to	H	'number'
do	to	LH	'two'
pu	pu	H	'deep in the mountain'
bu	pu	LH	'boy'
sa	sa	H	'earth'
za	sa	LH	'eat'

A number of other Tibetan dialects have the same tonal patterns although there is some variation (Duanmu (1992b)). For example, the H pattern can be realized as HL on a long syllable, and the LH pattern can be realized as L on a short syllable or LHL on a long syllable. On disyllabic words, the H pattern can be realized as H-H or H-HL, and the LH pattern can be realized as L-H, L-HL, and less commonly, as LH-H and LH-HL.

In the H pattern, only the H part is related to the voiceless consonant; the final L in the HL variant can be attributed to a boundary tone. In the LH pattern, only the L part is related to the voiced consonant; the H part can be considered a default tone that every word (or tonal domain) must have. In any case, for onset consonants, tonogenesis theories only deal with the correlation of voiceless-H and voiced-L.

3.2.1.1. *Listener-based Theory*

Hombert et al. (1979, p. 38) offer a listener-based theory of tonogenesis. Their proposal is rephrased in (16).

(16) Listener-based theory (Hombert et al. (1979))

a. For intrinsic phonetic reasons, voiceless consonants slightly raise the F0 of the vowel, and voiced consonants slightly lower the F0 of the vowel.
b. These F0 perturbations on vowels are small but perceptible by listeners.
c. In certain circumstances listeners exaggerated the perturbation, as a result of which the F0 difference is extended through the entire vowel, giving rise to the development of tone.

Hombert et al. provide extensive evidence that voiceless consonants raise the F0 of a vowel, and voiced consonants lower it. They also offer some evidence that the F0 perturbation is perceptible. Finally, they cite some reports that F0 perturbation can help listeners distinguish between voiceless and voiced stops in certain contexts.

Kingston (1986) offers a variant of the listener-based theory. He points out that F0 contour can enhance the contrast between voiceless and voiced consonants. In order to create a better perceptual contrast, speakers may use a higher tone after a voiceless consonant and a lower tone after a voiced consonant. When such a habit is stabilized, or "phonologized", tones become part of the phonological system. A similar view is offered in Kingston and Diehl (1994), according to which voiceless-H and voiced-L occur because each pair of features enhance each other acoustically.

3.2.1.2. *Feature-spreading Theory*

Halle and Stevens (1971) offer a different theory of tonogenesis. In their proposal, tone and voicing are different realizations of the same articulatory gestures: the stiffness of the vocal cords. Specifically, vocal cord tension is realized in obstruent consonants as the state of voicing and in vowels as tone, and the tonogenesis process is the spreading of vocal cord features from the consonant to the vowel. If we use [+stiff] to represent a voiceless consonant or a high tone and [–stiff] to represent a voiced consonant or a low tone, tonogenesis can be analyzed as in (17).

(17) Before feature spreading (no tone)

pa	ba
|	|
[+stiff]	[–stiff]

After feature spreading

pá	bà
|/	|/
[+stiff]	[–stiff]
(H tone)	(L tone)

Halle and Stevens also offered an analysis of Korean, to which we return below.[5]

3.2.1.3. *A Comparison*

The two tonogenesis theories have certain similarities. For example, both assume that the articulation of voicing inherently affects F0. The theories also have differences. For example, Halle and Stevens assume that voicing and tone involve the same articulatory gesture whereas Hombert et al. do not. A consequence is that the Halle-Stevens analysis does not have to claim that the F0 perturbation is audible before feature spreading, because the feature for tone is already there in the consonants. Another difference is that Halle and Stevens assume that voicing and tone each involves just one articulatory gesture the stiffness of the vocal cords, whereas Hombert et al. do not. In other words, the listener-based theory leaves open the possibility that voicing or tone each involves several possible articulatory mechanisms.

Hombert et al. (1979, pp. 42–43) raise two criticisms of the Halle-Stevens theory. First, consonant voicing does not have the same F0 effect on the preceding vowel as on the following vowel. Second, there is a lack of physiological evidence for the proposed vocal cord tension (stiffness) (Hirose and Gay (1972)). The first criticism may be answered by the fact that a VCV sequence is usually syllabified as V.CV, where there is a syllable boundary (if not also a word boundary) between C and the preceding V, which may have reduced C's influence (see Krakow (1999) for the effect of syllable boundary on phonetic and phonological processes).[6] The second criticism is directed towards a specific assumption of vocal cord tension, which Hombert et al. call "horizontal" tension (by the cricothyroid movement, for example). In contrast, Hombert et al. argue that there is evidence for the activity of "vertical" vocal cord tension (by vertical movement of the larynx) during the articulation of voicing (and tone). If feature-spreading theory adopts vertical vocal cord tension, which it can, it is no longer subject to the same criticism.

The difference between the two tonogenesis theories is not crucial for the present proposal. What is important is that as long as the consonant-tone correlation is voiceless-H and voiced-L, reasonable analyses are available. But if the correlation goes beyond voiceless-H and voiced-L, the analyses become problematic.

3.2.2. *Analysis of Korean*

If lax stops are underlyingly voiced, the consonant-tone correlation in Korean is straightforward: it is another case of voiceless-H and voiced-L. We have discussed two approaches to tonogenesis. Since the difference does not seem crucial, we present our analysis in terms of feature spreading. Before doing that, it is necessary to discuss tonal representation in more detail.

In early tonal models (such as the Halle-Stevens model), tone is made of only one component, which cannot account for tone split, such as when a rise splits into a high rise and a low rise (see below). According to more recent studies (Yip (1980; 2002), Bao (1990; 1999), and Duanmu (1992a;

2000)), tone has two components: Register (upper vs. lower) and Pitch (H vs. L). The articulatory mechanisms for tone remain controversial. We offer an interpretation based on Zemlin (1998), who identifies two basic mechanisms for pitch control: the tension of the vocalis muscles, and the cricothyroid movement. Register corresponds to voicing, which is probably related to the stiffness of the vocalis muscles, where upper is [+stiff] and lower is [–stiff]. Pitch corresponds to the regular tonal features H and L, which are probably related to the cricothyroid movement. Register and Pitch features can combine to give four level tones, interpreted in (18).

(18)	Register	Pitch	Tonal interpretation
	[+stiff (upper),	H]	regular/clear high
	[+stiff (upper),	L]	regular/clear low
	[–stiff (lower),	H]	lowered/murmured high
	[–stiff (lower),	L]	lowered/murmured low

The upper or [+stiff] Register corresponds to clear voice in the vowel. The lower or [–stiff] Register corresponds to murmured voice in the vowel (also called ‘breathy voice’, but it is different from [+aspirated]).

One advantage of the model is that it can account for how a rising tone can split into two, a high rise and a low rise. For example, Shanghai has two word tones, LH and HL. LH has two variations, a low rise after an (originally) voiced onset (with a murmured quality) and a high rise after an (originally) voiceless onset. The two rising tones can be analyzed in (19), assuming that voice is specified as [–stiff], and voiceless is unspecified (Ito and Mester (1986)).

(19)	LH		LH		LH		LH
	/pa/	→	[pa]		/ba/	→	[pa]
					[–stiff]		[–stiff]
	‘to place’				‘to queue’		

The high rise is a regular rise. The low rise is one where the [–stiff] feature has shifted from the voiced onset to the vowel, which also give the vowel a murmured quality.

When a language uses only two tonal levels, [+stiff] tends to co-occur with H, and [–stiff] tends to co-occur with L. In other words, [–stiff] (voice in obstruents, or lower/murmured Register in vowels) can trigger L, and [+stiff] (voiceless in obstruents, or upper/clear Register in vowels) can trigger H. The fact that one feature can trigger another is not new. For example, [–voice] stops often trigger [+aspirated], and [+back] vowels often trigger [+round]. According to Stevens and Keyser (1989) and Kingston and Diehl (1994), features that tend to co-occur usually enhance each other phonetically. Under such considerations, the effect of [stiff] in Korean is analyzed in (20), where traditional names are shown in parentheses.

(20)

Values of [stiff]	–	+	+
As voicing in stops	b ("lax")	p ("tense")	p^h (aspirated)
Tone in vowels	L	H	H

The creation of tone on the vowel can be analyzed in several ways, depending on whether [stiff] (or [voice]) can be underspecified (Ito and Mester (1986), Steriade (1987), Archangeli (1988)) and how the H tone is assigned. We will consider two analyses, one assuming that both [+stiff] ([–voice]) and [–stiff] ([+voice]) are specified at the underlying level, and one assuming that only [–stiff] ([+voice]) is specified. The first analysis is shown in (21).

(21) Specifying both [+stiff] and [–stiff]

<table>
<tr><td></td><td>Underlying</td><td>Spreading</td><td>Devoicing</td><td></td><td></td></tr>
<tr><td>Lax</td><td>b a
|
[–stiff]</td><td>L
b a
| /
[–stiff]</td><td>L
b̥ a
|
[–stiff]</td><td>or</td><td>L
p a
| |
[+stiff][–stiff]</td></tr>
<tr><td>Tense</td><td>p a
|
[+stiff]</td><td>H
p a
| /
[+stiff]</td><td>(no change)</td><td></td><td></td></tr>
<tr><td>Aspirated</td><td>pʰa
|
[+stiff]</td><td>H
pʰa
| /
[+stiff]</td><td>(no change)</td><td></td><td></td></tr>
</table>

Underlyingly, both [+stiff] and [–stiff] are specified. After the features spread to the vowel and create tones on it, the tense and aspirated stops remain unchanged, while the lax stop undergoes devoicing, which may be analyzed in three ways. First, according to Kingston and Diehl (1994), the lax stop remains phonologically [+voice] although it is realized phonetically as voiceless in initial position (and still phonetically different from the tense stop). On this view, there is no need to represent initial devoicing by changing the phonological feature. Second, the feature [–stiff] is delinked, creating a stop with unspecified voicing (represented as devoiced [b̥]). On this view, [b̥] can also differ from the tense [p] in various ways. Third, the feature is changed from [–stiff] to [+stiff]. On this view, the lax stop becomes the same as the tense stop featurally. However, since the lax stop is next to a low tone and the tense stop next to a high tone, the stops can still differ phonetically (see section 3.3). Finally, to get LH for the syllable with a lax stop, one can assume a further requirement that every word must contain H. We leave it open how to implement this requirement.

If we consider the initial lax stop to be [b̥], we seem to create a three-way contrast in voiceless stops again, as most previous analyses do. However, there is an important difference: We assume that underlyingly, there is only a two-way contrast in voiceless stops (voiceless aspirated and voiceless unaspirated) whereas most previous analyses require an underlying three-way contrast in voiceless stops. As a result, we do not need a new feature, such as [tense], and we do not over-predict possible stops.

Next consider the second analysis, in which [–stiff] (or [+voice]) is specified but [+stiff] (or [–voice]) is not (Ito and Mester (1986)). In this analysis, [–stiff] is specified for lax stops, but no value is specified for aspirated and tense stops. In addition, following the intonation model of Pierrehumbert (1980), we assume that Korean has a pitch accent H in neutral intonation. In (22) we show the analysis.

(22) Specifying [–stiff] only

	Underlying	Spreading	Pitch accent	Devoicing
		L	LH	LH
Lax	b a	b a	b a	p a
	[–stiff]	[–stiff]	[–stiff]	[–stiff]
			H	
Tense	p a	(no change)	p a	(no change)
			H	
Aspirated	p^ha	(no change)	p^ha	(no change)

The spreading of [–stiff] ([+voice]) from the lax stop to the vowel triggers L, which leads to LH when the pitch accent is assigned. The lax stop is then devoiced.[7] The tense and aspirated stops are unspecified for [stiff], so spreading and devoicing do not apply. In this analysis [-voice] is unspecified, so there is no featural difference between the devoiced lax stop and the tense stop at the surface level. In medial position there is no spreading of [–stiff], so the lax stop remains voiced, and no L is created on the vowel.

We leave it open which version of the analyses is better. As far as the present topic is concerned, all of them can explain the consonant-tone interaction within the standard tonogenesis theory. In addition, there is no need for a new feature. It is also worth noting that in our analysis, the vowel after an initial lax stop is [–stiff], which means that it is murmured, besides having a L tone. Our prediction is confirmed by phonetic results (see the data on H1-H2, a measure of murmur, in Cho et al. (2002)).

Before we end this section, let us consider two questions for our analysis, both raised by reviewers. First, why does devoicing (and consonant-tone interaction) occur in initial position only? The answer is that phonological rules are sensitive to prosodic boundaries. This assumption is made in all phonological analyses. In the present case, the devoicing rule is triggered by the beginning of an accentual phrase (Jun (1993; 1996)).

Second, if tonogenesis is based on local pitch perturbation, it is medial lax stops (which are voiced) that should trigger L tone, while initial lax stops (which are voiceless) should not. Since the Korean facts are the opposite, it should not be analyzed with tonogenesis theory. There are two problems in this criticism. First, it is quite common for the tonogenesis effect to occur in domain initial positions only; for example, it is true in both Lhasa Tibetan (Duanmu (1992b)) and Shanghai Chinese (section 5.2 below). Second, although local pitch perturbation may be a phonetic effect and so should not be sensitive to prosodic boundaries, the exaggeration by the listener or the spreading of a feature is not a pure phonetic effect any more. Instead, in the listener-based model, the listener may want to emphasize the contrast in domain initial position but not domain medial position. Similarly, in the feature-spreading model, the spreading rule may be sensitive to prosodic boundaries. Therefore, there is no reason to assume that Korean is exceptional to tonogenesis theory.

3.3. *Phonetic differences between initial tense and lax stops*

As discussed in section 2, initial tense and lax stops in Korean are phonetically quite different (Lisker and Abramson (1964), C.-W. Kim (1965; 1970), Han and Weitzman (1970), Abramson and Lisker (1972), Hardcastle (1973), Hirose et al. (1974), Kagaya (1974), Dart (1987), Silva (1992), M.-R. Cho Kim (1994), Cho (1996), Han (1996), Shimizu (1996), Ahn (1999), M.-R. Kim (2000)). It is worth noting though that such differences are not unique to Korean. Scholars studying consonant-tone interactions in Asian languages have long observed two clusters of properties, which have been called the tense-lax syndromes or the first register-second register syndromes (Haudricourt (1954), Matisoff (1973), Jenner et al. (1976), and references therein). The basic generalizations, some of which being informal, are summarized in (23).

(23)	Tense Syndrome	Lax Syndrome
	voiceless onset	voiced onset
	first register	second register
	higher tone	lower tone
	normal voice	murmured voice
	tense	lax
	clear	deep

It can be seen that the tense syndrome closely matches the tense stop in Korean, and the lax syndrome closely matches the lax stop in Korean. It is also relevant to note that, as in our analysis, the tense syndrome correlates with a voiceless onset consonant, and the lax syndrome correlates with a voiced onset consonant.

Given the properties of the syndromes, it is natural that Halle and Stevens (1971) proposed the feature [stiff vocal cords] for the tense (or voiceless) syndrome and [slack vocal cords] for the lax (or voiced) syndrome. Similarly, Kingston and Diehl (1994) use [+voice] for the lax Korean stop and [–voice] for the tense Korean stop. Both analyses, as well as ours, assume that there is only one pair of syndromes (the voiceless-voiced pair), instead of two pairs of syndromes (the voiceless-voiced pair and the tense-lax pair). There are two reasons for assuming just one pair. First, Korean does not offer sufficient evidence for a new feature [tense], as discussed above. Second, there is too much overlap between the voiceless-voiced pair and the tense-lax pair for them to be treated as entirely different cases.

How, then, do we explain the phonetic differences between tense and lax stops when they are both voiceless? There are several possible answers, depending on one's view of phonetic interpretation and underspecification. Let us consider three options. First, according to Kingston and Diehl (1994), the lax stop is phonologically voiced throughout although its phonetic realization can vary. In general, Kingston and Diehl (1994) assume that phonetic interpretations of a phonological representation need not be automatic but can be language specific. In Korean, the lax stop is a plain voiced stop, which is realized as voiceless initially, but it need not become entirely identical with the tense stop. Second, if some sounds can be unspecified at surface (Keating (1988), Steriade (1997)), then the initial lax stop can be represented as a devoiced [b̥] (for the labial place), which is still different from the voiceless [p]. Third, if one assumes no underspecification at surface, or if one assumes underspecification for voiceless sounds throughout, then initial lax and tense stops are represented the same way at surface (both [–voice] or both unspecified for [voice]). Even so, they still need not be phonetically identical since they occur in different environments: the lax stop is in a lax/voiced syndrome environment (next to a murmured, L-tone vowel) whereas the tense stop is in a tense/voiceless syndrome environment (next to a clear, H-tone vowel). In this regard, it is relevant to note a similar case in Standard Chinese (Beijing Mandarin), where the voiceless unaspirated /p/ is murmured before tone 3 (which is L, as in [pàn] 'board') and clear before tone 1 (which is H, as in [pán] 'class'), similar to lax and tense stops in Korean, respectively. It is worth keeping in mind that phonetic differences do not always warrant a phonological feature. For example, in English [i] is systematically longer in [bid] 'bead' than in [bit] 'beat', but there is no need to represent the two [i]'s differently. Similarly, the pitch contour is slightly but systematically higher on [i] and [u] than on [a], yet no one represents the difference with a phonological feature. Therefore, unless the phonetic differences between initial tense and lax stops play a contrastive role unambiguously, without additional differences elsewhere in the word, such as tonal differences, there is no need to introduce a new phonological feature.

Perception studies provide additional evidence for the present analysis. In word pairs like [t*al] and [tal] in Korean, if the contrast mainly lies in the initial stops, as traditional analyses assume, we expect the stop portion to carry more perceptual information. On the other hand, if the contrast also occurs in tone (e.g., [tál] vs. [d̥ăl]) or perhaps mainly in tone, as the present analysis assumes, we expect the vowel or rime portion to carry just as much perceptual information or perhaps more information. Evidence supports the present analysis. According to Cho (1996), M.-R. Kim (2000, chapter 5) and M.-R. Kim et al. (2002), in Korean word pairs like [t*al] and [tal] ([tál] and [d̥ăl]), the vocalic portion carries more contrast than the consonantal portion.

Finally, consider two further objections to our analysis. First, a reviewer points out that vocative chanting may present a problem for our analysis, to which we return in section 5. Second, a reviewer argues that in languages that have undergone tonogenesis, initial voiceless and voiced stops have lost all phonetic distinctions. In contrast, initial tense and lax stops in Korean remain distinct. Therefore, Korean is unique, and a new phonological feature is warranted. However, we know of no evidence for the belief that tonogenesis leads to complete phonetic neutralization of voiceless and voiced stops. Instead, phonetic studies on initial stops are generally lacking in languages where the voiceless-H and voiced-L relation is still present (that is, not obscured by subsequent changes, such as tonal "flip-flop" (Yue-

Hashimoto (1986)), whereby H becomes L and L becomes H). Where such studies exist, initial stops are not fully neutralized (see Cao and Maddieson (1992) on the Wu dialects of Chinese and the voiceless-voiced syndromes above). Therefore, we see no evidence that Korean is unusual in this regard.

3.4. *Summary*

We have argued that what used to be thought as minimal pairs for tense and lax stops, such as [t*al] and [tal], are in fact [tál] and [d̥ăl]/[tăl], which differ in tone. There is, therefore, no sufficient evidence that Korean has a genuine phonemic contrast between voiceless tense and voiceless lax stops. Instead, the standard features [voice] and [aspirated] are sufficient to account for the Korean facts. The present analysis also shows that the consonant-tone interaction in Korean is a standard case of voiceless-H and voiced-L, which is found in many other languages.

Like Kingston and Diehl (1994), we assume that the lax Korean stop is a plain voiced stop and that the consonant-tone interaction in Korean is voiceless-H and voiced-L. On the other hand, we differ from Kingston and Diehl in two ways. First, Kingston and Diehl assume that tonogenesis is based on feature enhancement instead of feature spreading, so it is necessary for them to assume that the initial lax stop remains voiced phonologically (even though it is not phonetically) in order for it to be enhanced by L. If the initial lax stop is devoiced, then there is no motivation for it to be enhanced by L unless one assumes feature spreading, as the present analysis does. Second, Kingston and Diehl do not explicitly discuss the representation of the tense stop in Korean, so it is unclear whether they would need a new feature.

4. Previous Analyses

We review seven approaches to Korean stops and the consonant-tone correlation. We call them (a) the three-way voicing analysis, (b) the [tense] analysis, (c) the three-way aspiration analysis, (d) the hybrid analysis, (e) the underlying tone analysis, (f) the geminate analysis, and (g) the breathiness analysis. We have discussed the proposal of Kingston and Diehl (1994) in section 3 and so will not repeat it here.

4.1. *The Three-way Voicing Analysis*

This approach originates from Halle and Stevens (1971). Following C.-W. Kim (1965), Halle and Stevens assume that Korean has three series of voiceless stops. To distinguish them, as well as a voiced series, which are allophones of the lax stops in medial position, Halle and Stevens propose two features for vocal cord tension: [stiff (vocal cords)] and [slack (vocal cords)]. Along with [spread (glottis)] (for aspirated stops), the features give six types of stops. When the consonant features spread to vowels, they create six states of vowels. The analysis is shown in (24) (Halle and Stevens (1971, p. 203)). The combination [+stiff, +slack] is thought to be impossible and so it is not shown.

(24)							
	[slack]	–	+	–	–	+	–
	[stiff]	–	–	+	–	–	+
	[spread]	–	–	–	+	+	+
	Stop types	b_1	b	p	p_k	$b^ɦ$	p^h
	Vowel	M	L	H	voiceless	breathy	??

Halle and Stevens (1971, pp. 203, 206–207) represent tense, lax, and aspirated Korean stops as [p p_k p^h] respectively, where the lax stop is [b] medially. However, for them the lax stop (which they call "moderately aspirated", following C.-W. Kim (1965)) should trigger a voiceless vowel. In addition, they did not explain what vowel quality [p^h] should trigger. Thus, Halle and Stevens cannot explain the consonant-tone correlation in Korean. This is understandable since the consonant-tone correlation was not fully known at the time.

One may revise the Halle-Stevens system by making two changes. First, one may assume that only vocal cord tension ([stiff] and [slack]) affects tone. Second, one may assume that the lax stop is not aspirated. With those changes, the possible stops, along with the tones they can trigger, are shown in (25). For consistency, we use C.-W. Kim's labels and phonetic symbols (interpreting [+stiff] as tense [*]).

(25)							
	[slack]	–	+	–	–	+	–
	[stiff]	–	–	+	–	–	+
	[spread]	–	–	–	+	+	+
	Stop types	p	b	p*	p^h	$b^ɦ$	p^{h*}
	Korean	lax	voiced	tense			aspirated
	Tones	M	L	H	M	L	H

In this analysis, the Korean aspirated stop is also tense. The consonant-tone interaction can be seen as the spreading of vocal cord features from the consonant to the vowel, illustrated in (26) for unaspirated stops. Although Korean only has two unaspirated stops, all the three are shown because they can in principle occur in the same language.

(26) Before feature spreading

“lax”	“tense”	
pa	p*a	ba
|	|	|
[–slack, –stiff]	[–slack, +stiff]	[+slack, –stiff]

After feature spreading

“lax”	“tense”	
pa	p*á	bà
| /	| /	| /
[–slack, –stiff]	[–slack, +stiff]	[+slack, –stiff]
(M tone)	(H tone)	(L tone)

What the Halle-Stevens theory predicts is that the Korean tones are H and M (or MH) instead of H and L (or LH) as we propose. However, since Korean has just two tonal levels, the difference between the two proposals is hard to distinguish.

Korean also has voiced consonants, which are all sonorants. The sonorant onsets trigger the same tone as lax stops, so they can be analyzed as [–slack, –stiff]. (According to Halle and Stevens (1971, p. 208), [–slack, –stiff] is phonetically voiceless in stops and phonetically voiced in sonorants.)

There remain three problems for the revised three-way voicing analysis. First, it assumes that Korean has three types of voiceless stops, but we argued in section 3 that the assumption is questionable. Second, it predicts six possible types of stops, but there is no evidence that any language uses so many or that any language contrasts [p b p*] or [p^h $b^ɦ$ p^h*]. Third, it predicts that it is possible for stops to trigger three different tonal levels (H, M, and L), but we are aware of no such evidence in any language.

4.2. *The [tense] Analysis*

This analysis assumes that besides [voice] and [aspirated], Korean has a feature [tense] (or [fortis]) so that the aspirated stop is [+aspirated, +tense, –voice], the tense stop is [–aspirated, +tense, –voice], and the lax stop is [–tense, –voice] (C.-W. Kim (1965), Kim-Renaud (1974), Ahn (1985), Gim (1997)). To account for the consonant-tone correlation, this analysis must assume that besides voiceless-H and voiced-L, there is another tonogenesis mechanism, which is [+tense]-H and [–tense]-L.

There are several problems with this analysis. First, it assumes that Korean has three sets of voiceless stops, which is questionable (see section 3). Second, with a new feature [tense], one predicts many potential stops that are not found in the world's languages.[8] Third, the [tense]-tone correlation is not found in any other language, and Korean remains an exception. For example, it has been shown that F0 can affect the perception of consonant voicing (Haggard et al. (1970), Fujimura (1971), Massaro and Cohen (1976), Whalen et al. (1993)), but it remains to be shown that a low tone favors the perception of lax stops. Jun (1996, pp. 104–105) cites some evidence that in Korean a low tone helps the perception of the lax stop in initial position; the same effect was reported in M.-R. Kim (2000, chapter 5). However, since Korean has already undergone tonal differentiation, what the evidence shows may be no more than the fact that Korean speakers know that an initial lax stop co-occurs with a low tone in their language instead of the fact that a low tone helps the perception of lax stops in general.

4.3. *The Three-way Aspiration Analysis*

This analysis assumes that Korean has three degrees of aspiration (vocal-cord constriction), whereby the aspirated stop is [+spread, –constricted], the tense stop is [–spread, +constricted], and the lax stop is [–constricted, –spread] (K.-H. Kim (1987), Lombardi (1991), Han (1992), Kang (1992), Jun (1993)).

Since [+constricted] is a feature for the glottal stop [ʔ], the analysis in effect considers the Korean aspirated, tense, and lax stops to be [p^h, $p^ʔ$, p] respectively. This leads to two problems. First, there is no explanation for the consonant-tone correlation. In particular, if the lax stop is a plain unaspirated voiceless stop, it should trigger H, instead of L. Second, to claim that the tense stop is a glottalized [$p^ʔ$], one must show that (a) the tense stop has the same glottal closure as [ʔ] and (b) the Korean tense stop is different from a plain voiceless stop such as that in Thai or Chinese. We are not aware of either kind of evidence. For example, a reviewer argues that the Korean tense stop is realized with narrowed glottis (C.-W. Kim (1970), Hirose et al. (1974), Kagaya (1974), D.-W. Kim et al. (1992), Jun et al. (1998)), so the feature [+constricted] is justified, but there are two problems with the argument. First, since the tense stop is [–spread] (unaspirated), we already predict glottal narrowing, so there is no need to assume [+constricted] in addition. It seems then that [+constricted] is used for the tense stop not because of phonetic evidence but because there is otherwise no way to distinguish it from the lax stop. Second, many researchers doubt the glottal analysis of the tense stop. For example, Lombardi (1991) says that her choice of [+constricted] was motivated by the fact that [tense] is a poorly defined feature, but it is unclear whether [+constricted] fits the Korean case. She also notes that Korean tense stops are not quite the same as glottalized stops in other languages (Lombardi (1991, pp. 124–125)). Similarly, Han (1992, p. 207) says that there is no clear motivation for her choice of [+constricted] over [tense]. In addition, she notes that the original meaning of [+constricted] refers to complete glottal closure (Halle and Stevens (1971)), yet tense Korean stops do not have complete glottal closure. C.-W. Kim (1965, p. 344) also argues against complete glottal closure in the tense stop because the air pressure behind oral closure continues to increase before release.

4.4. *The hybrid analysis*

Using privative features and underspecification, Iverson and Salmon (1995) and Ahn and Iverson (2001) offer a hybrid analysis, where the aspirated stop is [spread, stiff], the tense stop is [constricted, stiff], and the lax stop is fully unspecified. This analysis assumes three-way aspiration: [spread], [constricted], and unspecified. In addition, it assumes three-way voicing: [stiff] (voiceless), [slack] (voiced), and unspecified (the Korean lax stop, phonetically voiceless). As a result, it faces twice as many questions: the three-way voicing part faces the questions raised in section 4.1, and the three-way aspiration part faces the questions raised in section 4.3.

Jun (1996) offers a similar hybrid analysis but with binary features, where the aspirated stop is [+spread, +stiff], the tense stop is [+constricted, +stiff], and the lax stop is [–spread, –constricted, –stiff]. Aside from using binary features, this analysis is the same as that of Iverson and Salmon (1995), and so it faces the same questions.

4.5. *The Underlying-tone Analysis*

Jun (1993, p. 52) notes the problem in extending standard tonogenesis theories to the consonant-tone correlation in Korean. As she puts it:[9]

> It is well known that . . . the vowel onset after voiceless consonants has a higher fundamental frequency compared to that right after voiced consonants. However, since Korean stops are all voiceless, the fact that only the voiceless lax stop (at the beginning of an) Accentual Phrase starts with a low tone cannot be explained away as a consequence of the influence of a preceding consonant.

Since there is no satisfactory phonetic or phonological explanation for the consonant-tone correlation, some studies conclude that Korean tones are either underlyingly specified or assigned by rules that are either just partially related to consonant properties or not at all. Let us call this approach the underlying-tone analysis. We consider Jun (1990) and Jun (1993) in detail and discuss Jun (1996; 1998) briefly.

Jun (1990) assumes that Jeonnam (Chonnam) Korean has the tonal patterns HHL and LHL (which she calls "accentual patterns") and argues that one of them can be considered the basic (underlying) form. As she puts it (Jun (1990, p. 127)):

> Since there are two accentual patterns in Chonnam, we might assume both of the accentual patterns as basic and assign each accentual pattern directly to phrases depending on their first segments. On the other hand, we may also assume one of the accentual patterns as basic and derive the other pattern by phonological rules.

She decided to consider LHL to be the basic form and use a rule to change it to HHL after tense and aspirated consonants because those consonants (both being voiceless) are known to raise F0. On the other hand, it is unclear why the rule does not apply after a lax consonant, which is also voiceless. Jun cites some phonetic reports that F0 is low after an initial lax stop, but that begs the same question: Why is the tone low after an initial lax stop? In summary, the LHL pattern is unrelated to initial consonants, and the rule to derive the HHL pattern cannot be fully attributed to phonetics.

Jun (1993, pp. 62–64) offers a somewhat different analysis of Chonnam. Consider her analysis of disyllabic words, such as those in (27).

(27)	[p^haraŋ]	H-HL	'blue'
	[p*algaŋ]	H-HL	'red'
	[param]	L-HL	'wind'
	[mallaŋ]	L-HL	'soft'

In such words an underlying H is linked to the second syllable (H is linked to the second mora when the first syllable is long, e.g., [mi:guk] LH-L 'America', but this pattern need not concern us). Then, if the initial consonant is aspirated or tense, H is spread to the initial syllable; otherwise L is added to the initial syllable. Finally, a final L is added by another rule. This is illustrated in (28).

	Underlying	H-Spread	Initial-L	Final-L
(28)	[p^haraŋ]	[p^haraŋ]	N/A	[p^haraŋ]
	H	H		H L
	[p*algaŋ]	[p*algaŋ]	N/A	[p*algaŋ]
	H	H		HL

```
[param]     N/A     [param]     [param]
   |                 |  |        |  |\
   H                 L  H        L  HL

[mallaŋ]    N/A     [mallaŋ]    [mallaŋ]
   |                 |  |        |  |\
   H                 L  H        L  HL
```

Although H-Spread and Initial-L refer to initial consonants, there is no explanation for the relation, as pointed out by Jun (1993, p. 52). In particular, there is no explanation why voiceless lax consonants should group with voiced consonants instead of other voiceless consonants. Thus, the two rules are essentially arbitrary.

Finally, in her more recent works, Jun (1996; 1998) discarded the rule approaches altogether and assumes two underlying tonal patterns, LHLH and HHLH, assigned post-lexically. Since both tonal patterns are underlying, there is no assumption that they are related to consonants in any way. This approach has another problem. According to the standard intonational model (Pierrehumbert (1980)), each pitch contour is associated with a different contextual meaning (statement, question, surprise, etc.). However, both LHLH and HHLH are used for the same contextual meaning (neutral statement). Thus, Korean is again unique in this regard.

In summary, in various versions of Jun's analysis, three types of voiceless stops are assumed. Like others, the analysis has three problems. First, the assumption of three types of voiceless stops is unsupported (see section 3). Second, the analysis over-predicts possible stops consonants. Third, there is no explanation for the consonant-tone correlation; instead, the correlation is treated as essentially arbitrary.

4.6. *The Geminate Analysis of Tense Consonants*

In this approach, Korean tense stops are thought to be geminates. We review two such proposals. The first assumes geminates without the feature [tense]. The second assumes both geminates and the feature [tense].

Schmidt (1995) and Avery and Idsardi (2000) propose that the "lax" stop is a plain voiceless unaspirated stop (e.g., /p/) and the "tense" stop is a geminate voiceless unaspirated stop (e.g., /pp/) even in initial position. This approach reduces the phonemic inventory by eliminating the tense series, but it is achieved at the expense of syllable structure. For example, Schmidt (1995, pp. 6–8) allows both onset clusters and coda clusters, such as [ttam] 'perspiration', [sont.tæ] 'dirt from hands', and [ipt.ta] 'wear (indicative)'. The resulting syllable structure is more complicated than what is otherwise maximally CGVC. There are two other problems as well. First, an initial tense stop is considerably shorter than a medial tense stop (Silva (1992, p. 120)), which does not support the assumption of initial geminates. Second, if tense and lax stops have the same features (except length), it is hard to explain why they trigger different tones.

Han (1992; 1996) proposes that Korean tense stops are geminates medially but singletons initially. However, since she assumes that there is a three-way contrast in initial stops, she needs an additional feature, which she uses [constricted glottis] (which for her is just another term for [tense]). Thus, her analysis faces the same problems mentioned before: (a) she assumes three kinds of voiceless stops in Korean, which is questionable, (b) she predicts too many potential stops, and (c) she cannot explain the consonant-tone correlation in Korean.

4.7. *The Breathiness Analysis*

In Korean, an initial syllable with a lax stop is often accompanied by breathiness. Two reviewers suggest that since the breathiness-L correlation is found in many Tibeto-Burman languages, it is natural to assume that the same mechanism is at work in Korean.

The proposal again has serious problems. First, in Tibeto-Burman languages, breathiness is not an independent feature by itself but a property that accompanies underlyingly or historically voiced consonants. In other words, there is no independent breathiness-L relation. Therefore, the breathiness-L thesis is still unique for Korean and basically hypothetical. Second, if breathiness is represented as [+spread (glottis)], then we still need a new feature to distinguish the aspirated stop from the lax stop since both are [+spread] and voiceless. The only solution is to assume [tense] again or to assume three-way voicing or three-way aspiration. In either case, we face the same problems as discussed above.

4.8. *Summary*

All the analyses reviewed above assume that Korean has a three-way contrast in voiceless stops. As we have argued, the assumption is questionable. In addition, such analyses have to wrestle with two other problems. First, to distinguish three voiceless stops, a new category is needed. However, the new category increases the number of possible consonants (or, in the geminate analysis, it complicates syllable structure in Korean), for which there is no independent evidence. Second, there is no satisfactory explanation for the consonant-tone correlation in Korean. If Korean does not have a three-way contrast in voiceless stops, as we have argued, neither problem arises.

5. Further Issues

In this section we discuss several further issues. Some of them address apparent problems for our analysis. Some of them provide further support for our analysis.

5.1. *Medial Voicing of "lax" Consonants*

We have assumed, following traditional descriptions (Martin (1954), C.-W. Kim (1965), Kim-Renaud (1974), Ahn (1985), Huh (1985), K.-H. Kim (1987)), that the lax stop is voiceless initially and voiced medially (that is, when occurring between voiced sounds). However, some recent studies have argued that the lax stop is not always voiced even medially. Let us consider two recent studies.

Silva (1992, p. 146) distinguishes four medial environments for lax stops, which can be called word medial, word initial, phrase initial, and syllable final. The last will be discussed later. The other three are shown in (29). The phonological phrase is derived from the edges of syntactic categories (Silva (1992, p. 79)). This is not quite the same as Jun (1993)'s accentual phrase. However, the difference need not concern us here.

(29)	Environment	Effect
	Word medial	Voiced
	Word initial	Voiced or voiceless
	Phrase initial	Voiceless

As Silva argues, both phrase and word boundaries can affect the voicing of lax stops. His analysis is rephrased in (30).

(30)	Environment	Effect
	Word medial	Voiceless → Voiced (obligatory)
	Word initial	Voiceless → Voiced (optional)
	Phrase initial	Voiceless (underlying)

Silva calls the obligatory rule a phonological rule and the optional rule a phonetic rule. Let us compare (30) with the present analysis, shown in (31).

(31)	Environment	Effect
	Word medial	Voiced (underlying)
	Word initial	Voiced → Voiceless (optional)
	Phrase initial	Voiced → Voiceless (obligatory)

As in the present analysis, word medial lax stops are always voiced. The word initial and phrase initial effects can also be accounted for if we assume that the condition for voiceless lax stops is accentual-phrase initial. Silvia's phrase initial is probably always accentual-phrase initial, whereas his word initial can sometimes be accentual-phrase initial (even if not phrase initial), where lax stops are voiceless, and sometimes not, where lax stops are voiced. Alternatively, we may assume an optional rule, as Silva suggests, that optionally applies in word initial position.

Jun (1994) offers a different analysis of medial voicing. She argues that the voicing of lax stops is not categorical but gradient, and therefore it should be treated as a phonetic effect instead of a phonological alternation. Since all studies consider lax stops to be voiceless initially, Jun's implication is that they are always voiceless, even medially. Let us consider her arguments.

First, Jun points out that word initial voicing of lax consonants is dependent on the speed of speech. The slower the speech, the fewer word initial lax stops are voiced. However, this can be reconciled with the traditional view because devoicing applies to accentual phrase initial positions, and the slower the speech, the more accentual phrases there are, and the more accentual phrases there are, the more devoicing there is. Consider the sentence in (32), with two speeds of speech, where brackets indicate accentual phrase boundaries.

(32)	Slow	[kaŋho-ga]	[paŋ-e]	[tɨlə]	[kanda].
	Fast	[kaŋho-ga]	[paŋ-e	dɨlə	ganda]
		Kangho-subject	room-to	enter	go-present

'Kangho enters into a room'

The sentence has four words, all of which start with a lax stop. In slow speech each word forms an accentual phrase, and all the four word initial lax stops are voiceless. In fast speech the sentence forms two accentual phrases, where the initial consonants of the last two words are now accentual-phrase medial and voiced.

Jun's second argument concerns word medial voicing. Like Silva (1992), Jun notes that lax consonants are more likely to be voiced word medially than word initially. However, unlike Silva, who reports word medial lax consonants to be always voiced, Jun reports that they are not always so in the $C_1V_1C_2V$ environment, where V_1 is a high vowel and C_2 is a lax stop. The data are shown in (33), from Jun (1994, p. 106), where we see a clear influence of C_1 on the voicing of C_2.

(33) Lax C_2 in $C_1V_1C_2V$ where V_1 is a high vowel (based on 597 tokens)

	C_2 voiceless	C_2 partly voiced	C_2 voiced
C_1 is fricative	158	32	49
C_1 is aspirated stop	69	7	44
C_1 is lax stop	9	19	90
C_1 is tense stop	6	4	110
Total	242	62	293

Jun argues that if medial voicing is phonological, the effect should be categorical, which probably means that it should apply in most cases no matter what C_1 is. Instead, the data shows a "gradient and quantitative" effect. Therefore, Jun concludes that medial voicing is not phonological.

However, to interpret the data properly, we must consider another piece of information. As Jun (1994, p. 106) points out, C_1 also influences the voicing of the high vowel V_1. In particular, when C_1 is a fricative or an aspirated stop, V_1 is often devoiced. Not surprisingly, C_2 is also devoiced in this environment. In contrast, when C_1 is an unaspirated stop (tense or lax), V_1 is usually voiced, and so is C_2. In other words, when a medial lax consonant is truly between two voiced sounds, it is overwhelmingly voiced or partly voiced. This is shown in (34). (In fact, since some high vowels might be devoiced after unaspirated stops as well, the percentage of voicing for medial lax C between truly voiced sounds might be still higher.)

(34) Lax C_2 in $C_1V_1C_2V$ when C_1 is an unaspirated stop and V_1 is a high vowel

	C_2 voiceless	C_2 partly voiced	C_2 voiced
Tokens	15	23	200
%	6%	10%	84%

Here 94% of the cases are voiced or partially voiced. When V_1 is a non-high vowel, which does not devoice easily, the voicing rate of C_2 should be at least as high. In other words, if we factor out high-vowel devoicing, medial lax consonants are overwhelmingly voiced or partly voiced. Clearly, this is a highly regular pattern and should be recognized phonologically, as traditional descriptions do. To dismiss medial voicing as gradient or phonologically irrelevant and to claim that lax stops are always voiceless is to miss an important generalization. It is also relevant to note that although high vowels do not always surface as fully voiced, they are still analyzed as voiced underlyingly. Thus, the fact that medial lax stops are not always voiced should not exclude the possibility that they are voiced underlyingly.

5.2. *Three-way Stop Contrast in Chinese Dialects*

In Wu dialects of Chinese there are also three series of stops, which are quite similar to those in Korean. There is a good amount of phonetic and phonological data on the Wu dialects (Zee and Maddieson (1979), Zhu (1995), Cao and Maddieson (1992) and references therein). In medial position, the stops occur as aspirated voiceless, unaspirated voiceless, and voiced. In addition, medial consonants have no effect on tone. Some examples from Shanghai are shown in (35).[10]

(35)	[və^{ʔ}.p^{h}a]	L-H	'not to send'
	[və^{ʔ}.pa]	L-H	'not to place'
	[və^{ʔ}.ba]	L-H	'not to queue'

In initial position, originally voiced stops trigger a lower tone and originally voiceless stops trigger a higher tone. Two examples are shown in (36).

(36)	LH		LH	LH		LH
	\/		\/	\/		\/
	/pa/	→	[pa]	/ba/	→	[pa]
				|		|
				[–stiff]		[–stiff]
	'to place'			'to queue'		

Here /pa/ 'to place' surfaces with a high rise and /ba/ 'to queue' surfaces with a low rise. In addition, underlyingly voiced stops are often murmured but voiceless in initial position (but voiced in medial position). For example, in (36) /ba/ surfaces as [pa] or [b̤a], where some breathiness accompany the initial [p] or [b̤].

In Chinese linguistics the three series of stops are analyzed as aspirated voiceless [p^{h}], unaspirated voiceless [p], and voiced [b]. This suggests that the Korean facts may not be unique and that an alternative approach is available.

5.3. *The notion of minimal pairs*

Strictly speaking, a minimal pair is a pair of words that differ in one sound only. We have argued that Korean does not have a minimal three-way contrast in voiceless initial stops because syllables with initial "tense" and "lax " stops also differ in tone. Consider the examples in (37), where the word with a tense stop has H whereas the word with a lax stop has LH.

(37)	Present	Traditional	
	[tál]	[t*al]	'daughter'
	[d̥ăl]/[tăl]	[tal]	'moon'

A reviewer argues that such words can count as a minimal pair. The reason is that, following Jun (1993; 1996), the intonational patterns are assigned post-lexically. If the words contrast lexically, before intonation is assigned, then they only differ in the stops. In a way this proposal is similar to our analysis, according to which the words indeed differ in the stops underlyingly ([t] vs. [d], see section 3). However, at the surface level, after the lax stop shifts the feature [–stiff] ([+voice]) to the vowel to create L, the contrast is shifted to the vowel. Our analysis is simpler in that (a) we do not need to assume special kinds of stops and (b) the consonant-tone correlation is also accounted for (the regular tonogenesis effect of voiceless-H and voiced-L). In contrast, Jun's analysis is more complicated because (a) it must assume special kinds of stops for Korean, and (b) it cannot account for the consonant-tone correlation.

The reviewer also argues that, even if we do not accept Jun's proposal, words like [t*ál] and [tăl] (our [tál] and [d̥ăl]/[tăl]) can still count as minimal pairs because tone is not lexically contrastive in Korean and can be ignored. We have answered this argument in section 3.1. We would like to add that to accept [t*ál] and [tăl] as minimal pairs is to relax the strict definition of minimal pairs. In other words, without relaxing the definition, Korean does not have genuine minimal pairs for voiceless tense and voiceless lax stops.[11]

It is worth noting that, while there are no minimal pairs for voiceless lax and voiceless tense stops, there are minimal pairs for voiced and voiceless unaspirated stops and affricates in medial position. Some examples are given in (38).

(38)	Underlying	Surface	Tone	Gloss
	/gən.baŋ/	[kən.baŋ]	L-H	'to be conceited'
	/gən.paŋ/	[kən.paŋ]	L-H	'biscuit'
	/gaŋ.dʒa/	[kaŋ.dʒa]	L-H	'strong man'
	/gaŋ.tʃa/	[kaŋ.tʃa]	L-H	'burning jealousy'
	/goŋ.dʒa/	[koŋ.dʒa]	L-H	'Confucius'
	/goŋ.tʃa/	[koŋ.tʃa]	L-H	'gratis'
	/goŋ.tʃʰa/	[koŋ.tʃʰa]	L-H	'allowance'

These are true minimal pairs, including tonal considerations. They establish genuine contrasts among voiced, voiceless unaspirated, and voiceless aspirated consonants.

5.4. *Vocative chanting*

Vocative chanting, originally discussed in Liberman (1975), is a style of speech used to call someone's attention, especially children, with a lengthened duration and a special intonation (such as '*Amanda, where are you?*'). Ko (2003) reports that in vocative chanting, the tonal contours of Korean words can differ from those in neutral speech. For example, consider the examples in (39).

(39)	Style	Name	Tone
	Neutral	Sang-Won	H-H
	Chanting	Sang-Won	L-H

In neutral speech, the name "Sang-Won" has the tone H-H, which is predictable from the voiceless initial [s]. However, in vocative chanting, the tone becomes L-H. A reviewer points out that, if word pairs like [t*al] and [tal] are chanted, they may have identical tones, and if they remain distinct, the contrast must lie in the stops themselves. Therefore, tense and lax stops are distinctive.

Let us consider the case in detail. Ko (2003) reports that in Seoul Korean all trisyllabic words (a disyllabic name plus a suffix) are chanted with the same tonal pattern L-H-M, regardless of the initial consonant. However, the initial consonant still has a systematic influence on tone, whereby aspirated and tense consonants lead to a higher L and other consonants lead to a lower L (the average difference between the higher L and the lower L is about 20 Hz). This means that there is still a tonal difference on the vowel, and the contrast does not entirely lie in the consonants.

If we only use the tonal features H and L, it is difficult to represent the difference between the higher L and the lower L. However, in the present tonal model (see section 3.2.2), in which tone has two components, Register and Pitch, the difference is easy to represent. This is shown in (40), assuming that [+stiff] is unspecified.

(40)	Tense	Lax	
	L	L	Pitch feature (part of chanting intonation)
	|	|	
	tal	tal	
		|	
		[–stiff]	Register feature

The L tone is assigned as part of the L-H-M intonation for chanting. Here the difference between the two words lies in the Register feature of the vowel. The vowel after the lax stop has the feature [-stiff] (shifted from the stop), which means that the vowel has a lowered L. In contrast, the vowel after the tense stop has a regular L (a higher L).

5.5. *Other Onset Consonants*

Besides stops, Korean also has fricatives and sonorants. The sonorants are voiced and trigger the L(H) pattern. Their analysis is similar to that of a voiced (or "lax") stop. The difference between a voiced stop and a sonorant is that sonorants do not devoice. An example is shown in (41), where the pitch accent H is not shown.

(41)	Underlying	Spreading	Devoicing	
	mal	màl	(no change)	'horse'
	|	|/		
	[–stiff]	[–stiff]		

The analysis shows that sonorants pattern with voiced obstruents in Korean. An anonymous reviewer points out that in some African languages, voiced obstruents can depress the pitch of a neighboring vowel, but sonorants do not. Similarly, in some African languages, voiced obstruents block H-spreading, voiceless obstruents block L-spreading, but sonorants allow both (Hyman and Schuh (1974)). This means that sonorants can, but do not always, behave like voiced obstruents. The same is true in Chinese: in some Chinese dialects sonorants pattern with voiced obstruents (lowering tone) whereas in others they split randomly so that sometimes they pattern with voiceless obstruents and sometimes they pattern with voiced obstruents. The Korean case, where sonorants pattern with voiced obstruents, is therefore not unusual.

Korean also has two dental fricatives. One has more aspiration and has been called lax; the other has been called tense. There is some disagreement on whether the former is in fact lax (Kim-Renaud (1974), Kagaya (1974), K.-H. Kim (1987), Jun (1993), Jun et al. (1998), Yoon (1998), Park (1999), M.-R. Kim (2000), Cho et al. (2002)). Two analyses are shown in (42). According to (42a), the contrast lies in [tense]. According to (42b), the contrast lies in [aspirated].

(42)		a.	b.	Tone	Gloss
	"Lax"	[sal]	[s^{h}al]	H	'flesh'
	"Tense"	[s*al]	[sal]	H	'rice'

According to Jun (1996) and M.-R. Kim (2000), both fricatives trigger H tone (see Figures 1 and 2 in the Appendix), supporting (42b). However, Cho et al. (2002) show that the "lax" fricative often becomes voiced [z] in medial position, similar to the medial voicing of lax stops. In addition, the vowel after the lax fricative has a greater H1-H2 value than that after the tense fricative, indicating what we would consider to be the lower Register (see section 3.2.2). If the lax fricative indeed patterns with lax stops, as Cho et al. argue, we would analyze the two fricatives as /z/ (for the "lax" one) and /s/ (for the "tense" one) underlyingly (following our analysis of lax and tense stops, see section 3) instead of /s^h/ and /s/ as proposed by M.-R. Kim (2000). It is worth noting that the speakers in M.-R. Kim (2000) were young whereas those in Cho et al. (2002) were old (between 55 and 75). It is possible that the two fricatives are /z/ and /s/ for old speakers and /s^h/ and /s/ for young speakers. On the other hand, the F0 values do not fully support the idea of a lax /s/ (or /z/). Consider the data in (43), from Cho et al. (2002, p. 216), where each F0 value is an average of the onset and the midpoint of the vowel.

(43)		s	s*	Lax	Tense	Aspirated
	Mean	137	145	126	144	147

While the F0 after an initial lax [s] is lower than that after initial tense and aspirated stops, it is much higher than that after initial lax stops. Thus, the analysis of the lax [s] remains unclear. It is worth noting that Cho et al. (2002) only used one word for initial tense [s*] and one word for initial lax [s]. It remains open whether more quantitative evidence will narrow the difference between M.-R. Kim (2000) and Cho et al. (2002).

Korean also has a consonant that is traditionally called "ieung". Its transcription varies in the literature. When it occurs in the onset position of a vowel initial syllable, some phonologists treat it as a pure orthographic placeholder, with no sound value, whereas others consider there to be still some glottal gesture (W.-J. Kim (1967), Huh (1985), K.-M. Lee (1972), Park (1983), S.-S. Kim (1995), Gim (1997)). When "ieung" occurs in the coda position, it is a velar nasal [ŋ]. Traditional Korean phonologists consider the two forms of "ieung" to be allophones of the same phoneme. In our view, there are two possible analyses. First, we may follow the tradition and assume that the underlying form is the velar nasal. This can explain why syllables with onset "ieung" trigger the L(H) pattern, as other voiced consonants do. After it triggers the L tone, the oral closure is deleted. The remaining part may be a voiced glottal sound [ɦ], or perhaps something else, which we will leave open. Alternatively, we may assume that the initial "ieung" is a voiced glottal sound [ɦ] (or it may be represented as having constricted but slack vocal cords, a "voiced glottal stop" of sort); this will also explain why it triggers a L tone. Since the phonetic reality and the phonological status of "ieung" remain somewhat controversial, we leave the final analysis open.

A reviewer points out that the analysis of "ieung" is a weak point in our analysis, which we agree. However, "ieung" is also a problem for every analysis. For example, in the analysis of Jun (1996; 1998), which the reviewer favors, there is still the question of why "ieung" patterns with voiced consonants. Therefore, we do not see a better alternative at this point.

5.6. *Why is There No Tone Split in English?*

As in Korean, voiced stops in English are often devoiced in initial position. One may ask why voicing has triggered tonal differentiation in Korean but not in English. There are many possibilities. For example, Korean may be influenced by Chinese, which itself has undergone tonogenesis (Baxter (1992)). Because we do not fully understand all those possibilities, we do not think anyone has any definite answer as to why some languages undergo tonogenesis and some do not, and we do not intend to offer one here.

5.7. *Difficulty in Producing and Perceiving Voiced Sounds by Korean Speakers*

It is often said that Korean learners of English have trouble producing and perceiving voiced obstruents. If Korean has voiced stops underlyingly, as we propose, one might wonder why Korean speakers have such difficulty. In particular, if the Korean lax labial stop is underlyingly [b], as it is in English, why do Korean speakers have difficulty learning [b] in English?

There are two possible answers. First, according to Iverson and Salmons (1995), English stops do not contrast in voicing but in aspiration. If so, English and Korean stops are not the same underlyingly. Second, how well a person learns a sound in a second language depends not only on the underlying representation but also on allophonic rules. Suppose both German and English have underlyingly voiced stops. This does not guarantee that German speakers will learn English stops without problem. One reason is that German has an allophonic rule for final devoicing whereas English does not. Thus, German learners of English may still have difficulty learning English stops. In Korean, voiced stops are obligatorily devoiced in accentual initial positions and in syllable final positions. In contrast, devoicing in English is not obligatory in such positions even though it often occurs initially. Such allophonic differences still require Korean speakers to learn English stops carefully.

5.8. *Coda neutralization*

All Korean stops in the coda are voiceless, unreleased, and completely neutralized except for the place of articulation (see Kim and Jongman (1996), H.-S. Kim (1998)). A reviewer points out that since coda stops are always voiceless, it is simpler if we assume that the lax stop is voiceless in the first place. However, the reviewer also notes that coda devoicing is a natural rule, which is found in many other languages. Besides, the lack of voicing and aspiration contrast in coda stops is a common property in other Asian languages, such as Chinese and Thai. Therefore, our analysis can still account for coda neutralization without assuming any special rule that is unique to Korean.

6. Conclusions

Traditional analyses of Korean often assume three sets of underlying voiceless stops, which are called "aspirated", "tense", and "lax". The assumption has lead to three theoretical problems in phonology. First, there are no genuine minimal pairs for tense vs. lax stops. Second, to distinguish three sets of voiceless stops, either a new feature [tense] is needed, or the contrast in voicing (or aspiration) must be increased from two to three. Either way there is an increase in the number of possible consonants in the world's languages, which lacks support beyond Korean. Third, there is no explanation for the consonant-tone correlation in Korean whereby tense stops trigger a high tone and lax stops trigger a low tone.

In our analysis, the "tense" stop is underlyingly a regular voiceless unaspirated stop, and the "lax" stop is underlyingly a regular voiced stop. In medial position, the contrast shows as it is. At the beginning of an accentual phrase, the lax stop is devoiced, and its [+voice] (or [–stiff]) feature is shifted to the following vowel, where it triggers a low tone. In this analysis, the main phonetic difference in word pairs such as [t*al] and [tal] does not lie in the stops themselves but in the tone of the vowel ([tál] vs. [d̥ăl]/[tăl]), in agreement with recent studies on Korean tone (Jun (1993), Cho (1996), M.-R. Kim (2000), M.-R. Kim et al. (2002)). The consonant-tone correlation is also natural – it is a standard case of voiceless-high and voiced-low, a tonogenesis effect that is found in many languages. There remain some phonetic differences in the initial stops, but they do not warrant a separate phonological feature because they do not carry phonological contrast independently. Our proposal offers a simpler analysis of Korean and a simpler theory of distinctive features, in that we assume no special features, or special kinds of consonants, or special consonant-tone correlation.

Our proposal is a radical departure from a traditional belief in Korean phonology, and consequently we have received many criticisms. What is remarkable is that there is little dispute over the basic facts in Korean, yet there remain two strikingly different conclusions. The difference seems to derive from two different views of language (and of Korean), which, for lack of better terms, we will call "the traditional view" and "our view", summarized in (41).[12, 13]

(44)

Traditional View	Our View
Languages are fundamentally different	Languages are fundamentally similar
Korean is unique	Korean may not be unique
Korean has special stops	Korean may not have special stops
Korean has special consonant-tone correlations	Korean may not have special consonant-tone correlations
The minimal pair can be defined flexibly	The minimal pair should be defined strictly

The traditional view is well expressed in the following words of Cho, Jun, and Ladefoged (2002, p. 225):

> The Korean consonant system is unique among the world's languages . . . The complexity of the phonetic properties of the three-way contrastive Korean stops implies that speech production is far more complicated than we can predict from simplified phonological representations or even the more sophisticated general speech production models that are currently available. We hope that the present study will serve as a substantial reference for future research bearing not only on issues about Korean obstruents and related issues addressing phonation types and voicing contrasts in other languages, but also on fine-grained modeling of speech production in general.

The statement is based on the belief that Korean has an unusual phonology, and so do many other languages. In this approach, it is quite natural to propose or accept unique features for Korean, or for other languages. In addition, phonological theory is expected to be "far more complicated" than it is today. Moreover, our arguments – that the traditional analysis of Korean complicates phonological theory – would be quite correct, but not as problems, because current phonological theory is much too "simplified".

In contrast, we believe that all languages are governed by similar phonological principles. It is possible that there are new phonological properties not yet known (and hence phonological theory may need significant revisions), but in order to establish them, compelling evidence is needed. In our view, there is no compelling evidence that Korean has unusual phonological properties.

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Appendix

F0 contours of monosyllabic and disyllabic words in Korean, grouped according to the word initial consonant, from M.-R. Kim (2000). The consonants are transcribed according to traditional analyses. [c] and [c^h] represent affricates, and [Y] represents the "ieung" initial, which is discussed in section 5.5.

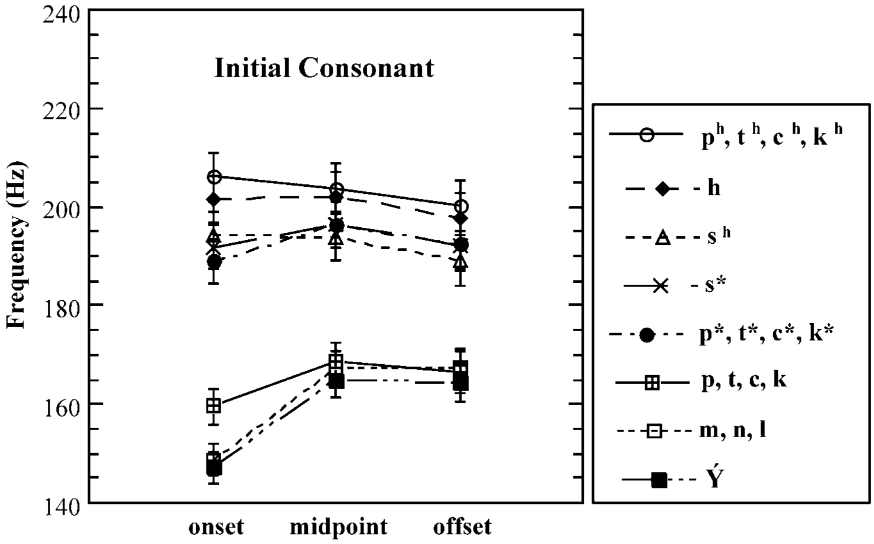

Figure 1. Overall mean F0 contour according to initial consonant based on measures taken at rime onset, midpoint, and offset. Data are averaged across three Jeonnam speakers (2 male and 1 female) and five Seoul speakers (3 male and 2 female). The standard error represents one standard deviation.

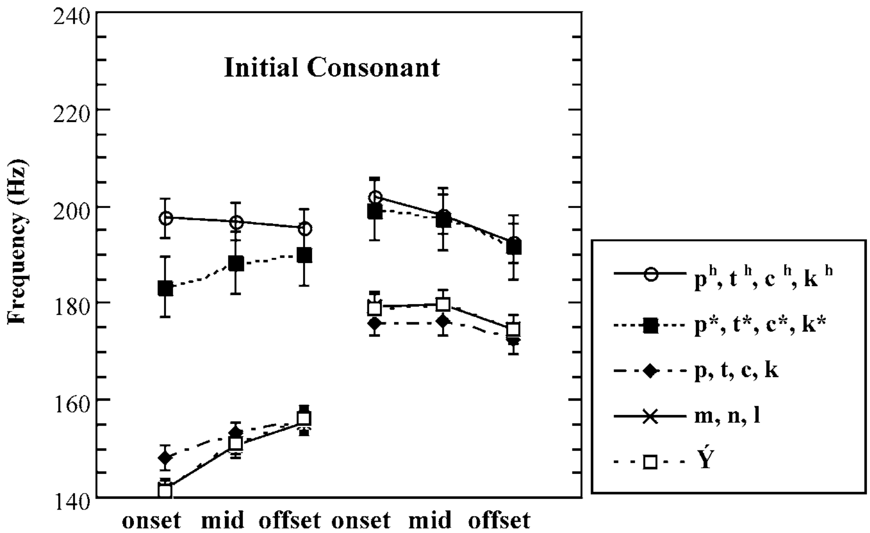

Figure 2. Overall mean F0 contours according to initial consonant based on measures taken at rime onset, midpoint, and offset of the first and second syllables. Data are averaged across three Jeonnam speakers (2 male and 1 female) and five Seoul speakers (3 male and 2 female). The standard error represents one standard deviation.

NOTES

[1] Gim's (1969; 1975) reports were based on auditory impression. Also, he transcribes the tone for syllables with lax and voiced onset consonants as MH. Since Korean does not contrast L and M, we follow Jun and M.-R. Kim and transcribe the tone as LH.

[2] It is worth pointing out that although Jun uses tonal features H and L to represent pitch contours in Korean, she does not consider the pitch contours to be tone. Instead, she considers them to be intonation. As discussed above, we use tone to refer to all uses of tonal features, whether they are lexically specified or not.

[3] Ko (2003) expresses a different view. She considers the consonant effect on F0 in Korean to be strongly phonetic and that in English and French to be weakly phonetic. Therefore, neither should be represented with the tonal features H and L.

[4] Iverson and Salmons (1995) propose that English /k/ and /g/ underlyingly differ in [aspirated], not in [voice]. Their proposal does not change the conclusion that an underlying feature can be realized as a different feature at surface.

[5] It can be seen that the feature-spreading theory is compatible with the phonetic observation that consonant voicing causes local F0 perturbation even before the creation of tone. For example, consider a case without feature spreading, such as a H-toned syllable [bá], where [b] is [–stiff] and [á] is [+stiff]. When the gesture [–stiff] of [b] changes to [+stiff] of [a], there must be a short period of transition, which causes a local lowering of the F0 on [á].

[6] A reviewer argues that whereas the syllable boundary may affect phonological rules, such as feature spreading, it should not affect phonetic effects, such as local pitch-perturbation. However, we will argue below that the consonant-tone interaction in Korean is not purely a local pitch-perturbation, but also involves feature spreading.

[7] Two anonymous reviewers say that accentual-phrase initial lax stops can sometimes remain voiced. If so, the devoicing rule may be optional.

[8] McKinney (1990) examined two African languages, Tyap and Jju, that reportedly have voiced lenis and voiced fortis consonants. The difference turns out to lie mainly in aspiration.

[9] In the following quote, we changed the original word "initial" to "(at the beginning of)". We assume that the original wording, which was ungrammatical, was an oversight.

[10] A tonal domain in Chinese is a foot. See Duanmu (1999).

[11] Chao (1934) argues that there can sometimes be multiple solutions (known as "overanalysis" and "under-analysis") in phonemics and in what counts as a minimal pair. On the other hand, Ao (1992) and Duanmu (2002) argue that there is much less uncertainty than Chao thought. In any case, if the unusual features of Korean must depend on a loose definition of minimal pairs, the case is not compelling.

[12] There may be other positions in between the two presented here.

[13] The same dichotomy seems to exist in some other disciplines. For example, the anthropological linguist Rob Burling (personal communications) once remarked that there are two kinds of anthropologists. Upon seeing people of a new community, there are those who say, "Ah! They are so different from us!" And there are those who say, "Ah! They are just like us!"

REFERENCES

Abramson, Arthur S. and Leigh Lisker (1972) "Voice Timing in Korean stops," in *Proceedings of the 7th International Congress of Phonetic Sciences*, A. Rigault and R. Charbonneau (eds.), Mouton, The Hague, pp. 439–446.

Ahn, Hyunkee (1999) *Post-release Phonatory Processes in English and Korean: Acoustic Correlates and Implications for Korean Phonology*, PhD dissertation, University of Texas at Austin.

Ahn, Sang-Cheol (1985) *The Interplay of Phonology and Morphology in Korean*, PhD dissertation, University of Illinois, Urbana-Champaign.

Ahn, Sang-Cheol and Gregory K. Iverson (2001) "Post-Obstruent Tensing in Korean Reconsidered," *Harvard Studies in Korean Linguistics* IX, 107–116.

Ao, Benjamin X. P. (1992) "The Non-uniqueness Condition and the Segmentation of the Chinese Syllable," *Working Papers in Linguistics* 42, Ohio State University, pp. 1–25.

Archangeli, Diana (1988) "Aspects of Underspecification Theory," *Phonology* 5, 183–207.

Avery, Peter and William Idsardi (2000) "The Laryngeal Phonology of Korean," paper presented at the 74th Annual Meeting of the Linguistic Society of America, Chicago.

Bao, Zhiming (1990) *On the Nature of Tone*, PhD dissertation, MIT.

Bao, Zhiming (1999) *The Structure of Tone*, Oxford University Press, New York.

Baxter, William (1992) *A Handbook of Old Chinese Phonology*, Mouton de Gruyter, Berlin.

Cao, Jianfen and Ian Maddieson (1992) "An Exploration of Phonation Types in Wu Dialects of Chinese," *Journal of Phonetics* 20.1, 77–92.

Chao, Yuen-Ren (1934). "The Non-uniqueness of Phonemic Solutions of Phonetic Systems," *Bulletin of the Institute of History and Philology*, Academia Sinica 4.4, pp. 363–397. Reprinted in *Readings in Linguistics I*, Martin Joos (ed.), University of Chicago Press, Chicago, 1957, pp. 38–54.

Cho, Taehong (1996) *Vowel Correlates to Consonant Phonation: An Acoustic-perceptual Study of Korean Obstruent*s, M.A. thesis, University of Texas at Arlington.

Cho, Taehong, Sun-Ah Jun and Peter Ladefoged (2002) "Acoustic and Aerodynamic Correlates of Korean Stops and Fricatives," *Journal of Phonetics* 30.2, 193–228.

Choi, Chun-Tae (1995) *Godae gugeo umjeolgujowa yuseong jeohaeumedehan yeongu* [A Study of Syllable Structure and Voiced Obstruents in Old Korean], PhD dissertation, Kyemyeong University.

Dart, Sarah N. (1987) "An Aerodynamic Study of Korean Stop Consonants: Measurements and Modeling," *Journal of the Acoustical Society of America* 81.1, 138–147.

Duanmu, San (1992a) "A Featural Analysis of Some Onset-vowel Interactions," in M. Ratliff and E. Schiller (eds.), *Papers from the First Annual Meeting of the Southeast Asian Linguistics Society*, Tempe, Program for Southeast Asian Studies, Arizona State University, pp. 141–158.

Duanmu, San (1992b) "An Autosegmental Analysis of Tone in Four Tibetan Languages," *Linguistics of the Tibeto-Burman Area* 15.1, 65–91.

Duanmu, San (1999) "Metrical Structure and Tone: Evidence from Mandarin and Shanghai," *Journal of East Asian Linguistics* 8.1, 1–38.

Duanmu, San (2000) "Tone: An Overview," in L. L.-S. Cheng and R. Sybesma (eds.), *The First Glot International State-of-the-Article Book: The Latest in Linguistics*, Mouton de Gruyter, Berlin, pp. 251–286.

Duanmu, San (2002) *The Phonology of Standard Chinese* (paperback edition), Oxford University Press, Oxford.

Fujimura, Osamu (1971) "Remarks on Stop Consonants: Synthesis Experiments and Acoustic Cues," in L. L. Hammerich, R. Jakobson, and E. Zwirner (eds.), *Form and Substance: Phonetic and Linguistic Papers Presented to Eli Fischer-Jørgenson*, Akademisk Forlag, Copenhagen, pp. 221–232.

Gim, Cha-Gyun (1969) "Jeonnam bangeone seongjo [Tone in Jeonnam Korean]," *Hangul* 144, 142–171.

Gim, Cha-Gyun (1975) "Yeongnam and yeongdong bangeone seongjo [Tone in Yeongnam and Yeongdong Korean]," *Hangul* 155.

Gim, Cha-Gyun (1997) "Jeongdojajilgwa urimalui ummunhyeonsang [Gradient Features and Phonological Phenomena in Korean]," *Chungnam Nonmunjip* 24, 161–253.

Goldsmith, John (1981) "English as a Tone Language,"in D. L. Goyvaerts (ed.), *Phonology in the 1980's*, E. Story-Scientia, Ghent, Belgium, pp. 287–308.

Haggard, Mark P., S. Ambler, and M. Callow (1970) "Pitch as a Voicing Cue," *Journal of Acoustical Society of America* 47, 613–617.
Halle, Morris and Kenneth Stevens (1971) "A Note on Laryngeal Features," *Quarterly Progress Report* 101, 198–213.
Han, Jeong-Im (1992) "On the Korean Tensed Consonants and Tensification," *CLS* 28, 206–223.
Han, Jeong-Im (1996) *The Phonetics and Phonology of "Tense" and "Plain" Consonants in Korean*, PhD dissertation, Cornell University.
Han, Mieko S. and Raymond S. Weitzman (1970) "Acoustic Features of Korean /P, T, K/, /p, t, k/, and /p^h, t^h, k^h/," *Phonetica* 22, 112–128.
Hardcastle, William J. (1973) "Some Observations on the Tense-lax Distinction in Initial Stops in Korean," *Journal of Phonetics* 1, 263–272.
Hashimoto, Mantaro J. and Chang-Kyun Yu (1972) "Phonological Distinctions of Korean Consonants," *Eomunhak* 26, 49–61.
Haudricourt, Andre G. (1954) "De l'origine des tons du Viêtnamien," *Journal Asiatique* 242, 69–82.
Hirose, Hajime and Thomas Gay (1972) "The Activity of the Intrinsic Laryngeal Muscles in Voicing Control: An Electromyographic Study," *Phonetica* 25, 140–164.
Hirose, Hajaime, C.-Y Lee, and Tatsujiro Ushijima (1974). "Laryngeal Control in Korean Stop Production," *Journal of Phonetics* 2, 145–152.
Hombert, Jean-Marie, John J. Ohala, and William G. Ewan (1979) "Phonetic Explanation for the Development of Tones," *Language* 55, 37–58.
Hu, Tan (1980) "Zangyu (Lasa hua) shengdiao yanju [A Study of Tone in Lhasa Tibetan]," *Minzu Yuwen* 1, 22–36.
Huh, Wung (1985) *Gugeo eumunhak* [Korean phonology], Saemmunhwasa, Seoul, Korea.
Hyman, Larry and Russell G. Schuh (1974) "Universals of Tone Rules: Evidence from West Africa," *Linguistic Inquiry* 5, 81–115.
Ito, Junko, and Armin Mester (1986) "The Phonology of Voicing in Japanese," *Linguistic Inquiry* 17, 49–73.
Iverson, Gregory K. and Joseph C. Salmons (1995) "Aspiration and Laryngeal Representation in Germanic," *Phonology* 12, 369–396.
Jenner, Philip N., Laurence C. Thompson and Stanley Starosta (eds.) (1976) *Austroasiatic Studies*, Part I, Honolulu, University Press of Hawaii.
Jones, Daniel (1950) *The Phoneme: Its Nature and Use*, W. Heffner and Sons, Cambridge.
Jun, Sun-Ah (1990) "The Accentual Pattern and Prosody of the Chonnam Dialect of Korean," *Ohio State University Working Papers in Linguistics* 38, 121–140.
Jun, Sun-Ah (1993) *The Phonetics and Phonology of Korean Prosody*, PhD dissertation, The Ohio State University.
Jun, Sun-Ah (1994) "The Status of the Lenis Stop Voicing Rule in Korean," in Y.-K. Kim-Renaud (ed.), *Theoretical Issues in Korean Linguistics*, Center for the Study of Language and Information, Stanford University, pp. 101–114
Jun, Sun-Ah (1996) "Influence of Microprosody on Macroprosody: A Case of Phrase Initial Strengthening," *UCLA Working Papers in Phonetics* 92, 97–116.
Jun, Sun-Ah (1998) "The Accentual Phrase in the Korean Prosodic Hierarchy," *Phonology* 15.2, 189–226.
Jun, Sun-Ah, Mary E. Beckman, and Hyuck-Joon Lee (1998) "Fiberscopic Evidence for the Influence on Vowel Devoicing of the Glottal Configurations for Korean Obstruents," *UCLA Working Papers in Phonetics* 96, 43–68.
Kagaya, Ryohei (1974) "A Fiberoptic and Acoustic Study of Korean Stops, Affricates, and Fricatives," *Journal of Phonetics* 2, 161–180.
Kang, Ongmi (1992) *Korean Prosodic Phonology*, PhD dissertation, University of Washington.
Keating, Patricia A. (1988) "Underspecification in Phonetics," *Phonology* 5, 275–292.

Kim, Chin-Wu (1965) “On the Autonomy of the Tensity Feature in Stop Classification (with Special Reference to Korean Stops),” *Word* 21, 339–359.

Kim, Chin-Wu (1970) “A Theory of Aspiration,” *Phonetica* 21, 107–116.

Kim, Dae-Won, Hajime Hirose, and Seiji Niimi (1992) “A Fiberoptic Study of Laryngeal Gestures for Korean Intervocalic Stops,” *Annual-Bulletin-Research-Insititute-of-Logopedics-and-Phoniatrics* 26, 13–28.

Kim, Hyunsoon and Allard Jongman (1996) “Acoustic and Perceptual Evidence for Complete Neutralization of Manner of Articulation in Korean,” *Journal of Phonetics* 24, 295–312.

Kim, Hyunsoon (1998) “A Phonetic Characterization of Release and Nonrelease: The Case of Korean and English,” *Language Research* 34.2, 347–368.

Kim, Kee-Ho (1987) *The Phonological Representation of Distinctive Features: Korean Consonantal Phonolog*y, PhD dissertation, University of Iowa.

Kim, Mi-Ryoung (2000) *Segmental and Tonal Interactions in English and Korean: A Phonetic and Phonological Study*, PhD dissertation, The University of Michigan.

Kim, Mi-Ryoung, Patrice Beddor, and Julie Horrocks (2002) “The Contribution of Consonantal and Vocalic Information to the Perception of Korean Iinitial Stops,” *Journal of Phonetics* 30.1, 77–100.

Kim, Mi-Ran Cho (1994) *Acoustic Characteristics of Korean Stops and Perception of English Stop Consonants*, PhD dissertation, University of Wisconsin, Madison.

Kim, Seong-Soo (1995) “Changwon jiyeoge moksori yeongu [A study of sound in Changwon area],” *Urimal Yeongu* 5, 1–18.

Kim, Wan-Jin (1967) “Hangugeo baldalsasang [The Development of Korean],” *Hanguk Munhwasadegye* 5.

Kim-Renaud, Young-Key (1974) *Korean Consonantal Phonology*, PhD dissertation, University of Hawaii.

Kingston, John (1986) “Are F0 Differences after Stops Accidental or Deliberate?,” paper presented at the 11th meeting of the Acoustical Society of America, Spring 1986.

Kingston, John and Randy L. Diehl (1994) “Phonetic Knowledge,” *Language* 70, 419–454.

Ko, Eon-Suk (2003) “The Laryngeal Effect in Korean: Phonology or Phonetics?” in Jeroen van der Weijer, Vincent J. Heuven, and Harry van der Hulst (eds.), *The Phonological Spectrum, Volume I: Segmental Structure*, Current Issues in Linguistic Theory series no. 233, John Benjamns, Philadephia and Amsterdam, pp. 171–191.

Krakow, Rena A. (1999) “Physiological Organization of Syllables: a Review,” *Journal of Phonetics* 27.1, 23–54.

Lee, Beong-Geon (1985) *Hyundai Hangugeoui Saengseong Eumunron* [The Generative Phonology of Modern Korean], Ilji Co., Seoul, Korea.

Lee, Ki-Moon (1972) *Gugeo Eumunsa Yeongu* [A Study of Korean phonology], Tower Co., Seoul, Korea.

Liberman, Mark (1975) *The Intonational System of English*, PhD dissertation, MIT, Cambridge, Mass.

Lisker, Leigh and Arthur S. Abramson (1964) “A Cross-Language Study of Voicing in Initial Stops: Acoustical Measurements,” *Word* 20, 384–422.

Lombardi, Linda (1991) *Laryngeal Features and Laryngeal Neutralization*, PhD dissertation, University of Massachusetts Amherst.

Martin, Samuel E. (1954) *Korean Morphophonemics*, Linguistic Society of America, Baltimore.

Massaro, Dominic W. and Michael M. Cohen (1976) “The Contribution of Fundamental Frequency and Voice Onset Time to the /zi/-/si/ Distinction,” *Journal of the Acoustical Society America* 60, 704–717.

Matisoff, James A. (1973) “Tonogenesis in Southeast Asia,” in L. Hyman (ed.), *Consonant Types and Ton*e, Southern California Occasional Papers in Linguistics 1. Department of Linguistics, University of Southern California, Los Angeles, pp. 71–95.

McKinney, Norris P. (1990) "Temporal Characteristics of Fortis Stops and Affricates in Tyap and Jju," *Journal of Phonetics* 18, 255–266.

Moon, Yang-Soo (1974) "Yeoksa eoneohak [Historical Linguistics]," *Eoneoyeongu* 10.2, 1–7.

Oh, Jong-Gap (1981) *Gugeo yuseong jeohaeeumui byeoncheone gwanhan yeongu* [A Study of Korean Voiced Obstruents with Special Reference to /b, d, z, g/], PhD dissertation, Yeongnam University.

Park, H.-S. (1999) "The Phonetic Nature of the Phonological Contrast between the Lenis and Fortis Fricatives in Korean," in *Proceedings of the 14th International Congress of Phonetic Science (ICPhS 99)* 1, pp. 424–427.

Park, Jong-Hee (1983) *Gugeo eumunron yeongu* [A Study of Korean Phonology], WonGwang University Press, Korea.

Pierrehumbert, Janet B. (1980) *The Phonology and Phonetics of English Intonation*, PhD dissertation, MIT.

Schmidt, Deborah (1995) "Syllable Contact in Korea," *Linguistic Analysis* 25, 3–20.

Shimizu, Katsumasa (1996) *A Cross-language Study of Voicing Contrasts of Stop Consonants in Asian Languages*, Seibido Publishing, Tokyo.

Silva, David James (1992) *The Phonetics and Phonology of Stop Lenition in Korean*, PhD dissertation, Cornell University.

Steriade, Donca (1987) "Redundant Values," *Papers from the 23rd Annual Regional Meeting of the Chicago Linguistic Society*, Part 2: Parasession on Autosegmental and Metrical Phonology, pp. 339–362.

Steriade, Donca (1997) "Phonetics in Phonology: The Case of Laryngeal Neutralization," Ms, UCLA.

Stevens, Kenneth N. and Samuel Jay Keyser (1989) "Primary Features and Their Enhancement in Consonants," *Language* 65.1, 81–106.

Wang, Jenny Zhijie (1993) *The Geometry of Segmental Features in Beijing Mandarin*, PhD dissertation, University of Delaware, Newark, DE.

Wang, Jenny Zhijie (1997) "The Different Nature of Syllable-final Nasals in English and Chinese," *Xiandai Waiyu* 78, 17–29.

Whalen, Doug H., Arthur S. Abramson, Leigh Lisker, and Maria Mody (1993) "F0 Gives Voicing Information Even with Unambiguous Voice Onset Times," *Journal of the Acoustical Society America* 93.4, 2152–2159.

Xu, Yi (1986) "Putonghua yinlian de shengxue yuyin texing [Acoustic Properties of Syllable junctures in Standard Chinese]," *Zhongguo Yuwen* 1986.5, 353–360.

Yip, Moira (1980) *The Tonal Phonology of Chinese*, PhD dissertation, MIT.

Yip, Moira (2002) *Tone*. Cambridge University Press, Cambridge.

Yoon, K. (1998) *An Acoustic Analysis of Korean Aspirated and Tense Alveolar Fricatives Using Multi-Speech*, M.A. thesis, University of Kansas.

Yue-Hashimoto, Anne O. (1986) "Tonal Flip-flop in Chinese Dialects," *Journal of Chinese Linguistics* 14.2, 161–183.

Zee, Eric and Ian Maddieson (1979) "Tones and Tone Sandhi in Shanghai: Phonetic Evidence and Phonological Analysis," *UCLA Working Papers in Phonetics* 45, 93–129. Department of Linguistics, University of California, Los Angeles.

Zemlin, Willard R. (1998) *Speech and Hearing Science; Anatomy and Physiology*, 4th edition. Allyn and Bacon, Boston.

Zhu, Xiaonong (1995) *Shanghai Tonetics*, PhD dissertation, Australian National University, Canberra.

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